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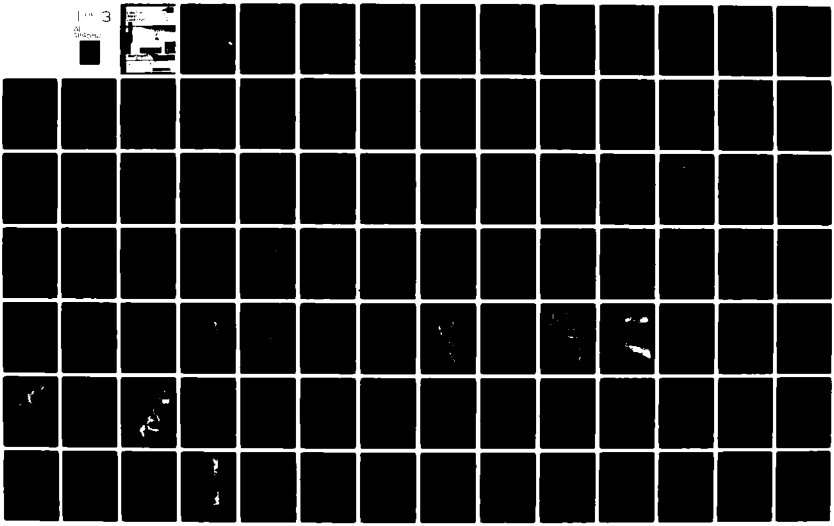

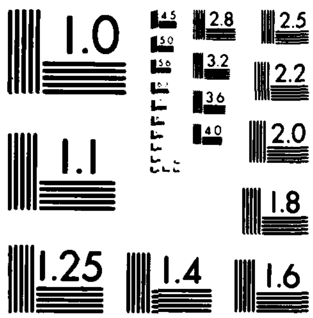

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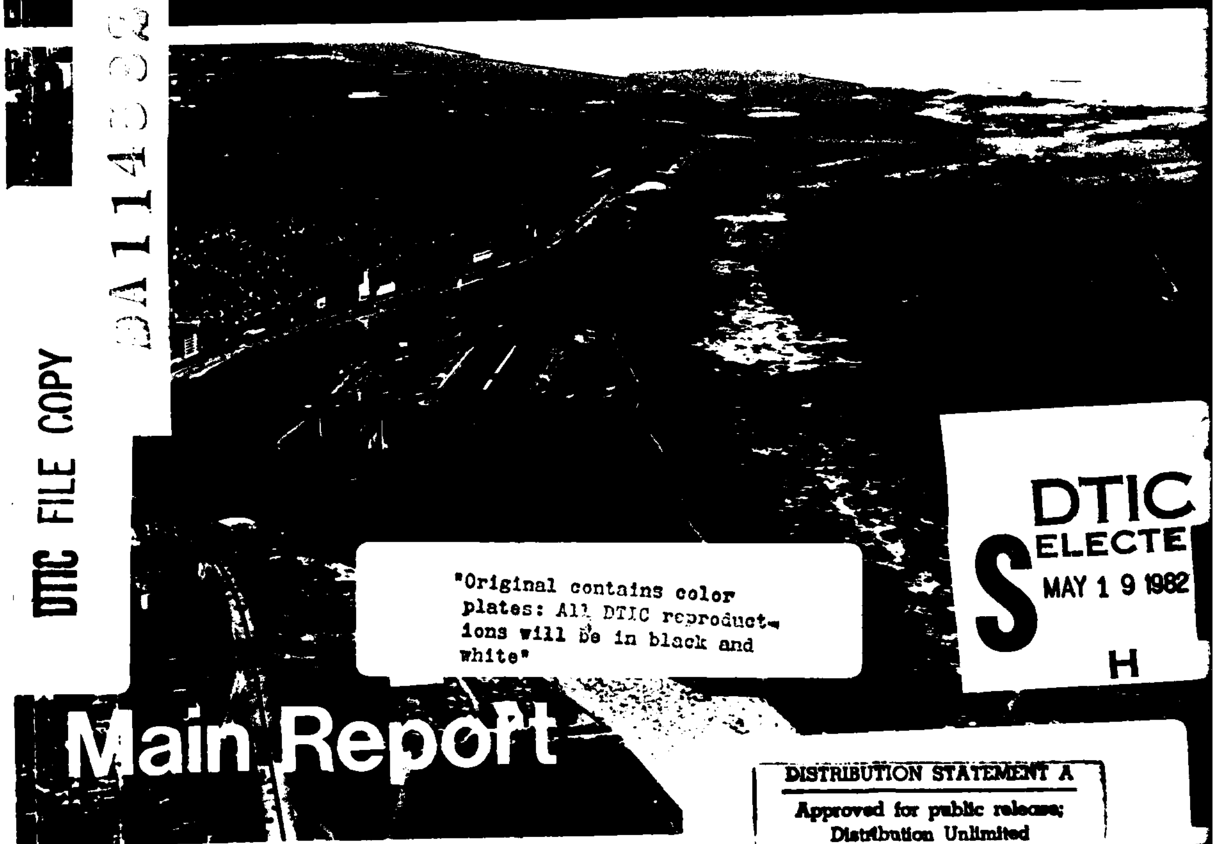

Main Report

International Lake Erie Regulation Study Board
International Joint Commission

July 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In 1977, the IJC (a permanent bilateral commission set up by Canada and the United States to oversee Canada - U.S. boundary water issues) established the Study Board to determine the possibilities for limited regulation of Lake Erie. The study came about mainly as a result of record high water levels on Lakes Erie, St. Clair, and Michigan-Huron in the early 1970's. The Report presents the types of control works required in the Niagara River at Buffalo, New York - Fort Erie, Ontario to carry out limited regulation, the costs of
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20. these works, and the economic and environmental interests affected. The possibilities of enlarging the St. Lawrence River are also presented since such measures would be required if Lake Erie were regulated.

Limited regulation of Lake Erie would have the effect of lowering that lake's water levels and those of the lakes upstream. As a result, flood and erosion damages on those lakes would be somewhat reduced. Recreational beach interests would also experience some benefits. At the same time, however, commercial navigation, recreational boating, and hydroelectric power interests would experience losses. The effects of limited regulation of Lake Erie on the environmental interests would be generally adverse.

Eight appendices are also available.

LAKE ERIE REGULATION STUDY

REPORT TO THE

INTERNATIONAL JOINT COMMISSION

BY THE

INTERNATIONAL LAKE ERIE REGULATION STUDY BOARD

(UNDER THE REFERENCE OF FEBRUARY 21, 1977)

JULY 1981

INTERNATIONAL LAKE ERIE REGULATION STUDY BOARD

3 August 1981

International Joint Commission
Washington, DC and
Ottawa, Ontario

Dear Commissioners:

The International Lake Erie Regulation Study Board is pleased to submit herewith its Report on the Regulation of Lake Erie Water Levels under the assignment given to it under the Reference of February 21, 1977. The conclusions and recommendations reached by the Board are summarized in Section 8 of this report.

The details of the studies and investigations carried out by the Board are contained in eight appendices to the main report.

Respectfully submitted,

Members for Canada	Members for United States
Derek M. Foulds	Scott B. Smith
D. M. Foulds, Chairman	Brigadier General Scott B. Smith, Chairman
F. Santerre	Wayne S. Nichols
F. Santerre	W. S. Nichols
J. E. Bryant	David F. Riley
J.E. Bryant	D. F. Riley
R. A. Walker	R. A. Cook
R. A. Walker	R. A. Cook

EXECUTIVE SUMMARY

In February 1977, the Governments of Canada and the United States requested the International Joint Commission to determine whether limited regulation of Lake Erie water levels would be in the public interest of both countries. The request came about as a result of record high water levels on Lake Erie and Lakes Michigan-Huron in the early 1970's, and as a result of the Commission's recommendation to the Governments in its 1976 report entitled, "Further Regulation of the Great Lakes." These record high water levels resulted in extensive flood and erosion damages to shoreline properties on the lakes.

The Commission established the International Lake Erie Regulation Study Board to perform the investigations. The Board established a working committee and subcommittees to deal with studies on regulation, regulatory works, coastal zone (or shore property), hydroelectric power, the environment and recreation, and navigation. Ad hoc groups were also established to study and make recommendations on the economic parameters to be used in this study and to inform the public of study activities. The Board conducted a series of public meetings to present the preliminary findings and to obtain the views and comments of the public before preparing this report.

Limited regulation of Lake Erie would involve increasing its outflows during periods of above average water supplies to the upper Great Lakes from which Lake Erie receives over 80 percent of its water. This requires regulatory works, which would act to enlarge the size of the outlet of Lake Erie, in the Buffalo, New York-Fort Erie, Ontario area. The works would be opened during periods of above average supplies and thus lower the high levels of Lake Erie. When water supplies to the upper Great Lakes were below average, the works would be operated to permit Lake Erie outflows which would have occurred had the works not been built.

Out of a number of possible Niagara regulatory works plans, three were selected for detailed analysis as follows:

1. the modification of the existing Black Rock Navigation Lock to provide an outflow increase of about 4,000 cubic feet per second (cfs);

2. a diversion channel across Squaw Island equipped with a control structure to provide an outflow increase of about 10,000 cfs; and,

3. channel enlargement in the Niagara River together with a compensatory structure in the vicinity of the Peace Bridge to provide an outflow increase of about 25,000 cfs.

By comparison, the long-term average Niagara River flow is about 200,000 cfs. Thus, these increases would represent 2 to 12 percent of the average river flow.

The effects of Lake Erie regulation plans on the water levels and outflows of the Great Lakes-St. Lawrence River system were evaluated in detail. In addition, the economic impacts of regulation on the major users of the Great

Lakes, which include coastal zone, hydroelectric power, navigation, and recreational beaches and boating interests were estimated. The evaluation of environmental impacts was basically qualitative, and relied heavily on existing data.

Limited regulation of Lake Erie would have the effect of lowering that lake's water levels and those of the lakes upstream. As a result, flood and erosion damages on those lakes would be somewhat reduced. Recreational beach interests would also experience some benefits. At the same time, however, commercial navigation, recreational boating, and hydroelectric power interests would experience losses. The effects of limited regulation of Lake Erie on the environmental interests would be generally adverse.

Adverse effects would also occur on Lake Ontario and the St. Lawrence River, unless measures were taken to mitigate such effects. These measures would include changes to the present plan for regulating the outflow of Lake Ontario, and channel enlargements in the International and Canadian Reaches of the St. Lawrence River. Channel enlargements in the Canadian Reach, at the Lachine area near Montreal, Quebec, would be similar to those studied in the Canada-Quebec study of flow regulation. Such enlargements, however, would not mitigate any possible adverse effects in the Montreal area and downstream.

Overall, it was determined that there would be economic losses far outweighing any benefits derived from limited regulation of Lake Erie. The magnitude of the losses as compared to the benefits is such that no reasonable changes in assumptions or evaluative techniques could result in net benefits approaching the cost of the Niagara regulatory works.

In summary, the Board concluded the following:

1. LIMITED REGULATION OF LAKE ERIE COULD BE ACHIEVED BY CONSTRUCTING REGULATORY WORKS NEAR THE HEAD OF THE NIAGARA RIVER. HOWEVER, THE COSTS OF SUCH WORKS ARE NOT ECONOMICALLY JUSTIFIED.

2. LIMITED REGULATION OF LAKE ERIE WOULD RESULT IN THAT LAKE'S MAXIMUM, MEAN, AND MINIMUM WATER LEVEL BEING LOWERED. SOME OF THIS LOWERING EFFECT WOULD ALSO BE TRANSMITTED TO THE UPPER GREAT LAKES. THIS LOWERING WOULD BE DUE TO INCREASED LAKE ERIE OUTFLOW DURING PERIODS OF ABOVE AVERAGE WATER SUPPLIES TO THE UPPER GREAT LAKES.

3. LIMITED REGULATION OF LAKE ERIE WOULD BRING ABOUT ECONOMIC BENEFITS TO COASTAL ZONE AND RECREATIONAL BEACH INTERESTS. HOWEVER, THESE BENEFITS WOULD BE MORE THAN OFFSET BY LOSSES TO COMMERCIAL NAVIGATION, RECREATIONAL BOATING AND HYDROELECTRIC POWER INTERESTS.

4. THE OVERALL ECONOMIC IMPACT EXPECTED FROM LIMITED REGULATION OF LAKE ERIE IS NEGATIVE. THERE ARE INSUFFICIENT BENEFITS TO OFFSET THE COSTS OF THE REGULATORY AND REMEDIAL WORKS.

5. LIMITED REGULATION OF LAKE ERIE WOULD RESULT IN AN INCREASE IN THE FREQUENCY OF OCCURRENCES OF HIGH OUTFLOWS FROM LAKE ONTARIO, INDICATING A REQUIREMENT TO ENLARGE ITS OUTLET IN ORDER TO MEET THE NEEDS STATED IN CATEGORY 3 STUDIES. IN ADDITION, THE EXISTING PHYSICAL DIMENSIONS OF THE ST. LAWRENCE RIVER WERE NOT ADEQUATE TO ACCOMMODATE THE HIGH SUPPLIES OF WATER TO LAKE ONTARIO IN THE EARLY 1970's AND AT THE SAME TIME SATISFY ALL THE COMMISSION'S CRITERIA AND OTHER REQUIREMENTS FOR THE REGULATION OF THAT LAKE. TO ACCOMMODATE THE LAKE ERIE OUTFLOWS UNDER LIMITED REGULATION OF LAKE ERIE, AND THESE HIGH SUPPLIES, REMEDIAL CHANNEL ENLARGEMENTS WOULD BE NECESSARY IN CERTAIN REACHES OF THE ST. LAWRENCE RIVER.

6. CHANNEL ENLARGEMENTS IN THE ST. LAWRENCE RIVER COULD PROVIDE BENEFITS TO LAKE ONTARIO COASTAL ZONE INTERESTS, BUT THE COSTS WOULD NOT BE ECONOMICALLY JUSTIFIED.

7. LIMITED REGULATION OF LAKE ERIE WOULD GENERALLY HAVE A NET ADVERSE IMPACT ON THE ENVIRONMENT EXCEPT FOR CERTAIN WATER QUALITY ASPECTS, SUCH AS TURBIDITY AND PHOSPHORUS, WHERE A SMALL POSITIVE BENEFIT WOULD ACCRUE.

8. THERE IS A LACK OF CLEAR UNDERSTANDING BY SOME OF THE PUBLIC OF THE VARIOUS NATURAL AND MAN-MADE FACTORS AFFECTING THE GREAT LAKES WATER LEVELS AND THE REASONS FOR THE EXTREME HIGH AND LOW WATER LEVELS.

In light of the above conclusions, the Board recommends that:

1. THIS STUDY OF LIMITED REGULATION OF LAKE ERIE SHOULD BE TERMINATED;

2. A PUBLIC INFORMATION PROGRAM SHOULD BE ENCOURAGED BY THE COMMISSION; AND,

3. COASTAL ZONE MANAGEMENT PRACTICES SHOULD BE ENCOURAGED BY THE COMMISSION AS A MEANS OF REDUCING FLOOD AND EROSION DAMAGES ALONG THE GREAT LAKES SHORELINE.

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APPENDIX A - LAKE REGULATION

A detailed description of the various factors which govern the water supply to the Great Lakes-St. Lawrence River System and affect the response of the system to this supply along with documentation of the development and hydrologic evaluation of plans for limited regulation of Lake Erie.

APPENDIX B - REGULATORY WORKS

A description of design criteria and methods used and design and cost estimates of the regulatory and remedial works required in the Niagara and St. Lawrence Rivers to facilitate limited regulation of Lake Erie.

APPENDIX C - COASTAL ZONE

A documentation of the methodology developed to estimate in economic terms the effects of changes in water level regimes on erosion and inundation of the shoreline and water intakes and of the detailed economic evaluations of plans for limited regulation of Lake Erie.

APPENDIX D - COMMERCIAL NAVIGATION

A documentation of the methodology applied in the assessment of the effects on shipping using the Great Lakes-St. Lawrence navigation system as a consequence of changes in lake level regimes and the evaluation of the economic effects on navigation of regime changes that would take place under plans for limited regulation of Lake Erie.

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Section 1
INTRODUCTION

1.1 Authority

By letters dated 21 February 1977, the Governments of the United States and Canada requested the International Joint Commission (IJC) to undertake a study to determine the possibilities for limited regulation of Lake Erie and the consequent effects throughout the Great Lakes Basin. The request was made pursuant to Arcticle IX of the Boundary Waters Treaty of 1909, and in response to the Commission's 1976 Report entitled "Further Regulation of the Great Lakes" which recommends that the Governments appprove such a study. The 1977 Reference requested that the Commission

> "undertake a study to determine the possibilities for limited regulation of Lake Erie, taking into account the applicable Orders of Approval of the Commission and recommendations of the Canada-Quebec study of flow regulation in the Montreal region. In particular, this study should examine into and report upon the effects of such limited regulation with respect to: (a) Domestic water supply and sanitation; (b) Navigation; (c) Water supply for power generation and industrial purposes; (d) Agriculture; (e) Shore property, both public and private; (f) Flood control; (g) Fish and wildlife, and other environmental aspects; (h) Public recreation; and (i) Such other effects and implications which the Commission may deem appropriate and relevant."

> "The Commission, consistent with the principle of systemic regulation of the Great Lakes, which is endorsed by the two Governments, should consider such effects in light of anticipated impacts throughout the Basin, including the International and Canadian Reaches of the St. Lawrence River."

> "In the event that the Commission should find that new or altered works or other measures examined pursuant to this Reference would be economically and environmentally practicable in light of the above stated considerations, it shall estimate the costs of such works or measures and indicate how the various interests on either side of the boundary would be benefitted or adversely affected thereby. The Commission shall likewise consider the need for remedial or compensating works, or nonstructural approaches, to protect interests potentially adversely affected by the proposed regulatory works or measures, and the approximate costs thereof. The Commission shall further consider as appropriate how such costs might be apportioned between the two Governments or concerned interests in each country."

As a result of this Reference, the Commission established the International Lake Erie Regulation Study Board on 3 May 1977 and appointed Board Members on 7 June 1977 to undertake the necessary investigations and studies. The Board's *Plan of Study, including Study cost estimates* was submitted to the Commission on 28 September 1977, and was approved by the Commission on 6 October 1977.

1.2 Purpose and Scope

Under the Reference, the Commission was requested:

1. to determine the possibilities for and the consequent effects throughout the Great Lakes basin of limited regulation of Lake Erie, taking into account the applicable Orders of Approval of the Commission and the recommendations of the Canada-Quebec study of regulation of flow in the Montreal region;

2. to determine what changes to existing works or other measures would be needed to accomplish limited regulation of Lake Erie;

3. to provide estimates of the costs of such measures and consider how those costs should be apportioned between the two countries; and

4. to indicate the probable effects, beneficial or adverse, of any regulation plans or measures proposed, in each country and throughout the basin, including the International and Canadian reaches of the St. Lawrence River.

This report addresses the feasibility of limited regulation of Lake Erie. Descriptions of Niagara regulatory works necessary to control the outflow from Lake Erie and of the channel enlargements and remedial works considered necessary in the St. Lawrence River to accommodate the regulation plans for Lakes Erie and Ontario are outlined along with their costs. The probable impacts, beneficial or adverse, of limited regulation on the various major interests in the Great Lakes-St. Lawrence System are presented. Those interests include hydro-electric power, commercial navigation, coastal zone (shore property), environmental and recreation. Detailed descriptions of the evaluations performed with respect to those interests are outlined in appendices to this report.

The geographic coverage of all major economic interests extends throughout the Great Lakes-St. Lawrence System. The hydro-electric interest relates to the facilities at the St. Marys River, Welland Canal, Niagara River, St. Lawrence River at Cornwall, Ontario - Massena, New York, and Hydro Quebec's facilities at Beauharnois-Cedars, Quebec. The commercial navigation interest takes into account all major ports and harbors in the Great Lakes and the connecting channels. Coastal zone coverage extends from Lake Superior to Trois Rivieres, Quebec in the St. Lawrence River. The effects of regulation on the environment (water quality, fisheries, and wildlife) and recreational interests (beaches and boating) were evaluated only for the lower lakes; between Port Huron, Michigan-Sarnia, Ontario to the Quebec-New York border with emphasis on the Lake Erie-Niagara River area. The study of recreational boating was carried out only in the United States, since time and funding constraints did not permit the extensive field survey of the Canadian recreational boating facilities.

The customary (English) units of measurement are used throughout the main report and its appendices. An English/metric conversion table is annexed to the main report and each appendix.

1.3 Study Method

The objective of limited regulation of Lake Erie is to reduce the extreme high water levels on that lake so as to reduce damages to the coastal zone riparian interests caused by flooding and erosion. Limited regulation would require the construction of regulatory works at the head of the Niagara River to modify the outflow of Lake Erie according to a regulation plan.

Any modification to the outflows of Lake Erie would affect the timing of a portion of the supply of water to Lake Ontario. It would also, to a lesser extent, affect the levels and outflows of the upper Great Lakes. The Board's study was divided into the following categories:

1. Category 1. Investigations of plans which would regulate Lake Erie, constrained by the Commission's present Orders of Approval for Lake Ontario regulation and channel limitations of the St. Lawrence River. Regulation of Lake Ontario would be conducted in accordance with Plan 1958-D.

2. Category 2. Investigations of plans which would regulate Lake Erie constrained by the Commission's present Orders of Approval for Lake Ontario regulation and channel limitations of the St. Lawrence River. Regulation of Lake Ontario would be conducted in accordance with Plan 1958-D modified to accommodate the Lake Erie regulation.

3. Category 3. Investigations of plans which would regulate Lake Erie constrained by the Commission's present Lake Ontario Orders of Approval. However, under this category the Lake Ontario regulation plan would be altered, and the channels of the St. Lawrence River modified as necessary to meet the requirements for the combined regulation of Lakes Erie and Ontario.

A fourth category (Category 4), giving consideration to plans which would regulate Lake Erie unconstrained by downstream channel limitations or Orders of Approval, was proposed in the Board's Plan of Study. The purpose was to identify means to reduce the losses to the coastal zone interest of Lake Ontario which would be expected as a result of limited regulation of Lake Erie. Enlargements of channels in the St. Lawrence River would have been investigated and a plan developed to regulate Lakes Erie and Ontario jointly. The Board noted that on the basis of findings from the first two categories, it would not be economically feasible to undertake limited regulation of Lake Erie. The Board also noted that the magnitude of the losses to the coastal zone interest on Lake Ontario, resulting from limited regulation of Lake Erie, would have been very small compared to the magnitude of the overall benefits to coastal zone interests on the other lakes. Thus, the Board concluded that it would be unnecessary to carry out Category 4 investigation. The Board presented this preliminary finding to the IJC at a briefing session on March 4, 1980, and by letter dated August 7, 1980, the Commission concurred with the Board and directed that the study of Category 4 be deleted.

Section 2 provides background information on the Great Lakes Basin.

One of the first steps in the investigation involved the use of historical data and certain assumed hydrologic conditions. That information was used to calculate the Great Lakes water levels and flows which would have occurred during the period from 1900 to 1976 if the present Lake Erie outlet condition and all man-made changes had been in effect over that period. Those levels and flows are termed the "basis-of-comparison" and their development is described in Section 3.

Section 4 describes how regulation plans for Lake Erie were developed, based on various objectives and criteria. These regulation plans were applied to the historical sequence of supplies of water to the Great Lakes basin. The levels and outflows which would have occurred from 1900 to 1976 resulting under those plans were compared with the basis-of-comparison. The differences between those plans and the basis-of-comparison are the effects of limited regulation of Lake Erie. Section 4 also describes the development of the adjusted basis-of-comparison, which was used to identify channel enlargements that would be required in the St. Lawrence River.

In order to increase the outflow from Lake Erie as required by the various regulation plans, several alternatives for structures in the Niagara River were examined and are described in Section 5. The preliminary engineering designs are outlined and estimates of cost for these alternatives are presented. Plans and cost estimates for enlarging the St. Lawrence River which could meet existing criteria of the IJC for the regulation of Lake Ontario are also presented.

Section 6 describes the hydrologic evaluation of the differences in levels and flows, and a general assessment of the effects of Great Lakes consumptive uses. It also provides the probable environmental and economic effects of these changes. The environmental evaluation of the regulation plans was a qualitative assessment and relates to three components: water quality, fish, and wildlife.

The economic evaluations of regulation plans were also made to determine effects on coastal zone, commercial navigation, hydro-electric power and recreational beaches and boating. These economic evaluations considered the estimated dollar value for a 50-year project period of benefits and losses under the new plans compared to those of the basis-of-comparison. Since it is impossible to forecast the weather 50 years into the future, the Study Board compared the performance of regulation plans assuming they were in effect over the historical period, 1900-1976 and the lakes experienced the same historical sequence of supplies. The differences in water levels and outflows between those plans and the basis-of-comparison serve as an indicator of the effects of limited regulation of Lake Erie throughout the project period, 1985-2034, provided that the supply sequences are no more extreme in the future than those of the past.

The Board's public information program is described in Section 7. The activities of the program are outlined along with a summary of public reactions to the Study and to the Board's preliminary findings.

Section 8 contains the Board's conclusions and recommendations. The detailed engineering, economic and environmental studies as well as the Board's public information activities are compiled in eight separate appendices to this report:

Appendix A - Lake Regulation

Appendix B - Regulatory Works

Appendix C - Coastal Zone

Appendix D - Commercial Navigation

Appendix E - Power

Appendix F - Environmental Effects

Appendix G - Recreational Beaches and Boating

Appendix H - Public Information Program

The Commission's Directive to the Board stated that "the Board shall submit its final report and appendices, if any, in the necessary quantity for public distribution, to the Commission no later than September 1, 1978." This target was not met for the following reasons: 1) Problems obtaining funding and other resources; 2) unforeseeable study activities including, for example, the development of new methodologies for evaluating impacts on the coastal zone and the environment, field investigations to provide data on recreational beaches and boating, and the update and refinement of the power and commercial navigation evaluation methodologies used by the Levels Board. The Board limited the geographic scope of the environmental study, confined field investigations to a minimum, and utilized the data and methodologies developed during the International Great Lakes Levels Board Study as much as possible.

1.4 Interim Briefing

On 4 March 1980, the Board briefed the Commission in Fort Erie, Ontario, in lieu of submitting an interim report as originally proposed in the Board's Plan of Study. The briefing covered the methodologies used in the detailed economic evaluations and the study results of Categories 1 and 2. A transcript of the proceedings is contained in a report entitled "IJC Briefing, 4 March 1980 by the International Lake Erie Regulation Study Board."

1.5 Public Hearings and Meetings

The Commission held public hearings in 1977, as follows:

Chateauguay, Quebec	November 15, 1977
Chicago, Illinois	November 16, 1977

Peoria, Illinois	November 17, 1977
Cleveland, Ohio	December 5, 1977
Buffalo, New York	December 6, 1977
Windsor, Ontario	December 7, 1977
Toronto, Ontario	December 8, 1977

Those hearings were for the purpose of receiving comments and testimony relevant to the study. The Board's Plan of Study was also available to the public prior to and at these hearings.

The Board and its Working Committee held the following public meetings:

Windsor, Ontario	October 28, 1980
Detroit, Michigan	October 28, 1980
Toledo, Ohio	October 29, 1980
Euclid, Ohio	October 30, 1980
Montreal, Quebec	November 4, 1980
Toronto, Ontario	November 5, 1980
Buffalo, New York	November 6, 1980

The purpose of those meetings was to provide an opportunity for the public to become familiar with the Study evaluation methodologies and to express views prior to the Board's formulation of the final report. The Board's preliminary results and findings were presented. A summary of the results of the public meetings is contained in "Appendix H - Public Information Program."

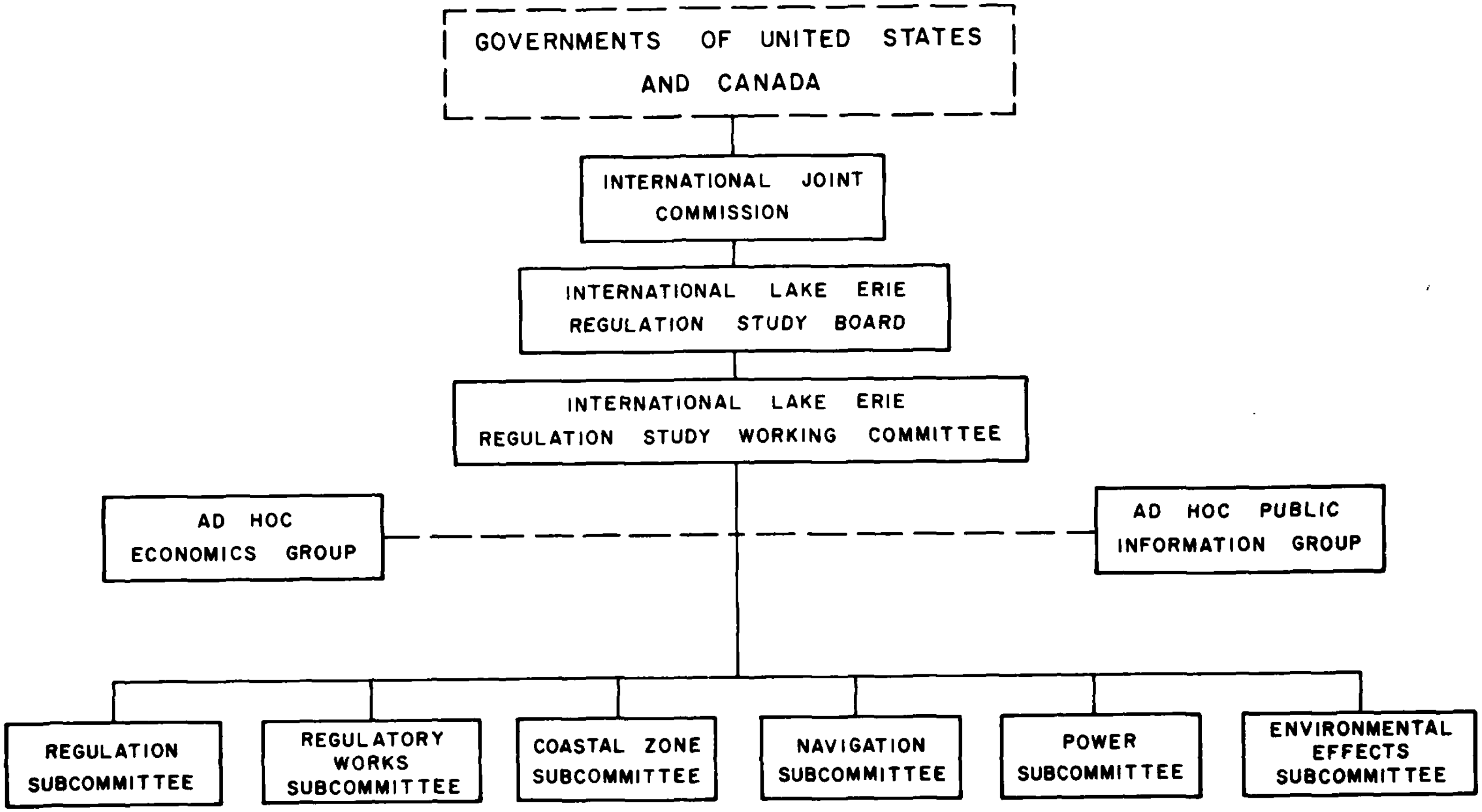
1.6 Study Organization

The United States Section of the Board is composed of members from each of the following affiliations: the U. S. Army Corps of Engineers, the U. S. Fish and Wildlife Service, the Ohio Department of Natural Resources, and the New York State Department of Environmental Conservation. The Canadian Section of the Board is composed of one member from the Environmental Management Service and the Canadian Wildlife Service, both of the Federal Department of the Environment, Ontario Hydro, and Hydro Quebec. The Board's first meeting was held on August 11, 1977.

Under authority of the Directive from the Commission, the International Lake Erie Regulation Study Board set up a Working Committee to assemble data, organize field activities, and conduct studies necessary to provide the information requested by the Commission. The first meeting of the Working Committee was held on 13 July 1977. In light of the extensive and multi-disciplinary nature of the investigation, the Working Committee established subcommittees to develop various plans for limited regulation of Lake Erie and to evaluate their effects. Ad hoc working groups were also established to examine specific problem areas.

The participants in the Working Committee and subcommittees came from a wide array of agencies throughout the Great Lakes-St. Lawrence River system. In addition to those listed above, agencies such as the U.S. Environmental Protection Agency, Great Lakes Basin Commission, the Canadian Ministry of Transport, the St. Lawrence Seaway Development Corporation, and Ontario Ministries of Natural Resources and the Environment were also included. Annex B is a list of Board and Working Committee membership.

The structure of the Board's organization is shown in Figure 1.



STRUCTURE OF STUDY ORGANIZATION

FIGURE 1

FIGURE 1

Section 2
EXISTING CONDITIONS

2.1 Geographic Description

2.1.1 Geographic Location

The Great Lakes-St. Lawrence System is comprised of Lakes Superior, Michigan, Huron, St. Clair, Erie, and Ontario, and their interconnecting channels: the St. Marys, St. Clair, Detroit, Niagara, and St. Lawrence Rivers (Figure 2). The entire system drains north-eastward through the St. Lawrence River emptying into the Gulf of St. Lawrence and the Atlantic Ocean.

The Great Lakes are bordered in the United States by eight States: Minnesota, Ohio, Wisconsin, Michigan, Indiana, Pennsylvania, Illinois, and New York. Two provinces, Ontario and Quebec, border the Canadian portion of the Great Lakes and the St. Lawrence River.

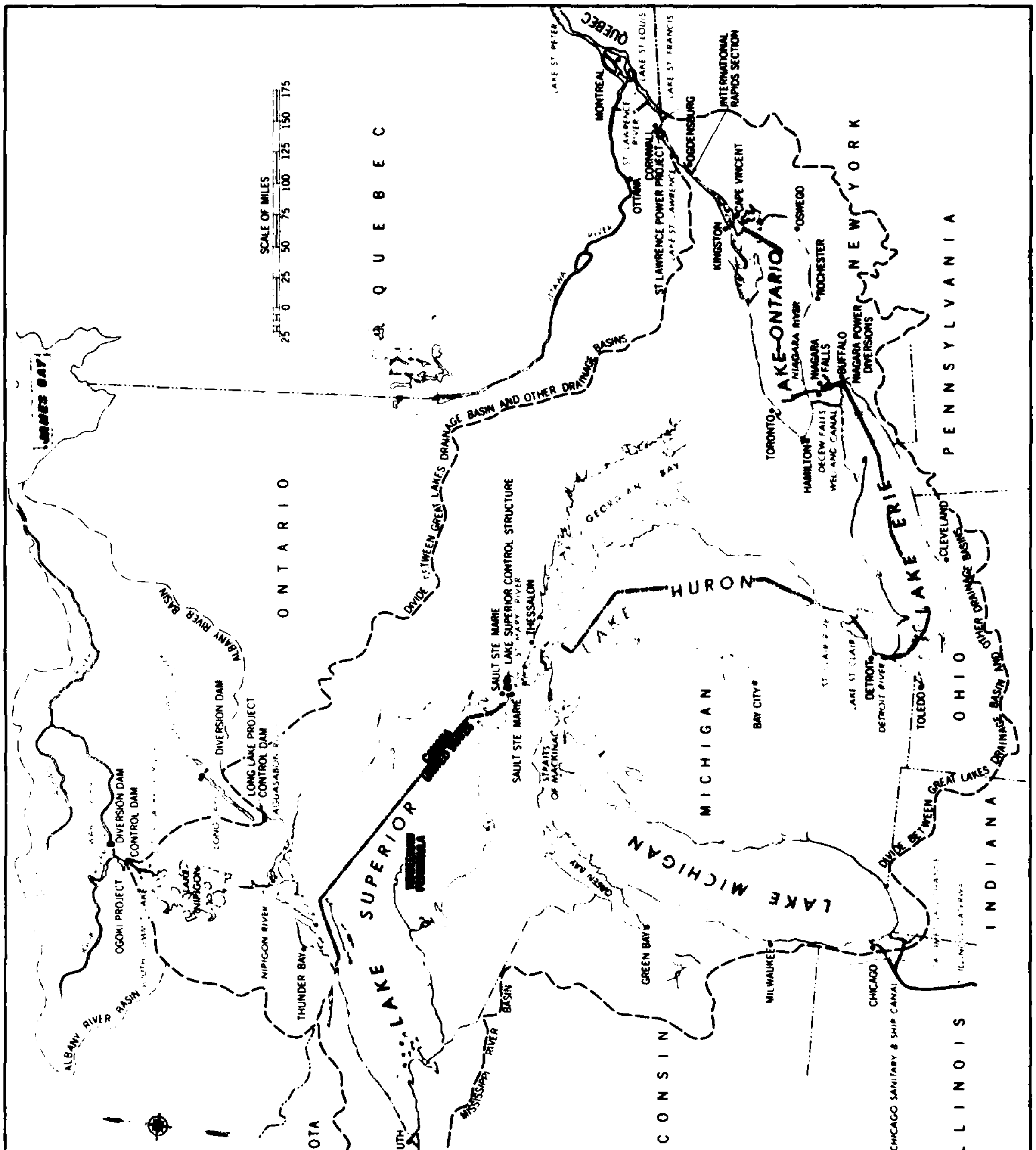
The Great Lakes watershed is situated between the northern latitudes of 40°30' and 50°50', and stretches approximately 700 miles in the north/south direction. In the east/west direction, the watershed extends between the longitudinal lines 75°00' and 93°10', a distance of about 900 miles. The total area of this drainage basin, including both land and water, is about 295,000 square miles (measured to Cornwall, Ontario-Massena, New York Powerhouse). Of this, 59 percent is located within the United States while the remaining 41 percent is situated within Canada. The surface water area of the Great Lakes and their connecting channels covers about 95,000 square miles, representing 32 percent of the drainage basin.

Lake Superior, at the head of the Great Lakes system, is both the largest and the deepest of the Great Lakes (Table 1). Lake Superior discharges into Lake Huron by way of the St. Marys River which is approximately 70 miles long and drops about 22 feet. Most of the fall in elevation within this river occurs at the St. Marys Rapids (Figure 3). The average discharge for the period 1900-1976 is 75,000 cubic feet per second (cfs).

Lakes Huron and Michigan stand at virtually the same level connected by the broad and deep Straits of Mackinac and they are usually treated as one lake in hydrologic and hydraulic considerations. Both are relatively large lakes and have very complex bathymetric profiles, particularly in the northern reaches which are underlain by Pre-Cambrian rock.

The St. Clair River, Lake St. Clair, and the Detroit River provide the outlet of Lake Huron to Lake Erie. The total fall within these interconnecting waters amounts to about 8 feet. The long-term average discharge of the St. Clair and Detroit Rivers are 180,000 cfs and 184,000 cfs, respectively.

Lake Erie is the southernmost lake within the Great Lakes system. This lake is also the shallowest of the Great Lakes having an average depth of



GREAT LAKES-ST. LAWRENCE RIVER DRAINAGE BASIN

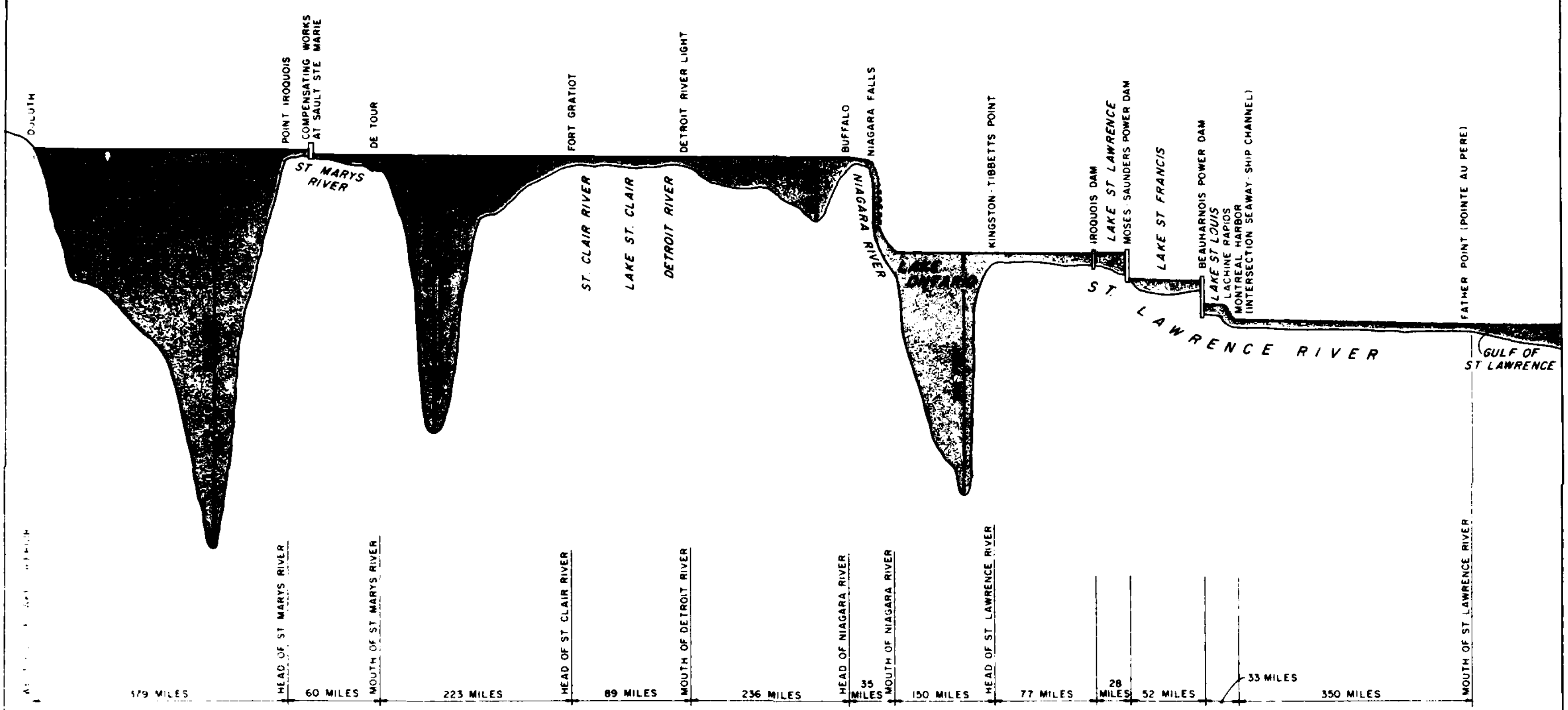
FIGURE 2

FIGURE 2

Table 1 - Dimensions of the Great Lakes

	Water Surface: Area (sq. mi.)	Volume (cu. mi.)	Shoreline Length: Mainland (mi.)	Shoreline Length: Island (mi.)	Depth: Average (ft.)	Depth: Maximum (ft.)
Lake Superior	31 700	2,900	1,729	997	483	1,330
St. Marys River	89	-	95	152	-	-
Lake Michigan	22,300	1,180	1,400	238	279	923
Lake Huron	23,000	850	1,850	1,977	195	750
St. Clair River	21	-	58	5	-	-
Lake St. Clair	430	-	130	127	-	21
Detroit River	39	-	60	72	-	-
Lake Erie	9,910	116	799	72	62	210
Niagara River	23	-	69	37	-	-
Lake Ontario	7,340	393	634	78	283	802
St. Lawrence River from Lake Ontario to Cornwall-Massena Powerhouse	235	-	301	352	-	-

NOTE: Values are measured at chart datum.
SOURCE: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 1977



WATER SURFACE ELEVATIONS (IGLD, 1955)		
	CHART (LOW WATER) DATUM	LONG-TERM AVERAGE (1900 - 1976)
LAKE SUPERIOR	600.0	600.4
LAKES MICHIGAN-HURON	576.8	578.7
LAKE ST. CLAIR	571.7	573.1
LAKE ERIE	568.6	570.4
LAKE ONTARIO	242.8	244.8

FIGURE 3

GREAT LAKES - ST. LAWRENCE RIVER PROFILE

FIGURE 3

only 62 feet. It is divided into three basins with the eastern basin being the deepest. The western basin is the shallowest with much of the lake bottom lying between 26-30 feet.

Lake Erie flows into Lake Ontario via the Niagara River which drops 326 feet. A small portion of the Lake Erie water also enters Lake Ontario by way of the Welland Canal. The long-term Lake Erie outflow has been about 203,000 cfs. Lake Ontario is the smallest of the Great Lakes, however, due to its great depth averaging 283 feet, it has a volume almost 3.5 times that of Lake Erie.

The St. Lawrence River is the outlet of Lake Ontario and extends approximately 540 miles to the Gulf of St. Lawrence while dropping approximately 245 feet. The long-term average discharge of the St. Lawrence River, measured at Cornwall-Massena, is 238,000 cfs. The Ottawa River which flows into the St. Lawrence River at Montreal and the flows of other tributaries result in an average St. Lawrence River flow of 325,000 cfs at a point just downstream from Montreal.

2.1.2 Physiography

The Great Lakes-St. Lawrence River System is contained largely within three physiographic regions. These are the Pre-Cambrian Shield to the north, the Central Lowlands in the southern portion of the Great Lakes, and the St. Lawrence Lowlands in the east. The present forms of these physiographic regions have resulted from the underlying bedrock type and structure.

The Pre-Cambrian rock was formed 1-1/2 billion years ago and is composed of metamorphic and igneous rocks. It surrounds most of Lake Superior and the northern shoreline of Lake Huron. This area is very rocky with little or no overburden and is primarily covered in forest.

The topography within the Central Lowlands of Lake Michigan, the southern end of Lake Huron, and of Lakes Erie and Ontario is generally flat to gently rolling with much of the area being used for agricultural purposes. The Lowlands are covered with debris left behind by glacial deposition and meltwater. They are predominately overlain by deposits of silt, clay, till, gravel and boulders.

The lake shorelines bordering the Central Lowlands are composed largely of unconsolidated materials. Sand beaches and dunes are common along the shores of Lakes Michigan, Huron, and parts of Lakes Ontario and Erie. Much of the remaining shoreline consists of till bluffs often experiencing severe erosion problems.

The St. Lawrence Lowlands refer to the wide flat valley occupied by the St. Lawrence River. It is underlain by sedimentary bedrock including limestone, shale, sandstone, and conglomerate.

Nearshore and bottom sediments of the lower Great Lakes are primarily composed of glacial deposits with occasional bedrock outcrops. These glacial deposits are mainly till. Post-glacial deposits occur as a result of

reworking of sediments on the crests of submerged moraines (e.g., Point Pelee, Ontario) and accumulation by littoral processes. In the upper lakes, nearshore and bottom sediments are generally sands, clays, and silts of glacial origin.

The drainage systems of the Great Lakes basin are characteristic of the types of topographic features of the region. The rivers which enter Lake Superior are characterized by rapid changes in elevation as they descend from the Pre-Cambrian Shield to the lake and feature many falls, rapids, swamps and lakes. The northern Lake Michigan and Lake Huron basins also have rivers typical of the Pre-Cambrian Shield. Rivers in the southern Lakes Michigan, Erie, and Ontario areas are characterized by regular slopes, few lakes and swamps, and well-defined channels. They drain glacial deposits and are often located in previous meltwater channels usually having broad flood plains which are frequently inundated by high water levels.

Since the retreat of the last ice advance, the earth's crust in the Great Lakes region has risen vertically with the greatest amount of uplift affecting the more northeastern part of the area. As time goes on, the water levels along the shores that are situated south and west of the lake outlet are rising. Similarly, water levels along the shores at localities north and east of the outlet are receding with respect to the land. A recent study has shown that the land around the Buffalo area, the outlet of Lake Erie, is rising with respect to Cleveland at a rate of about 0.2 foot per century.

The effect of differential crustal movement is not uniform; generally the rates around Lakes Superior and Ontario are greater than those around Lakes Michigan-Huron and Erie.

2.1.3 Climate

The Great Lakes basin has a continental climate which is moderated by the presence of the Great Lakes. The climate is characterized by four distinct seasons. The controls on this climate are the latitude, topography, and weather systems movements. Within the basin, there is much variability in climate within a single season, depending on the air mass in effect as well as the position in the basin. The latitudinal position within the basin is important as there is a significant variation in climate from south to north resulting from variations in hours of sunlight and the angle of solar radition. The basin is also influenced by Arctic air masses from the north and tropical air masses from the south. The climate is further complicated by the influence of Maritime air masses originating over the Pacific and the Atlantic Oceans.

In the winter, the dominating winds are from the west. In January, the middle and upper Great Lakes are affected by northwest and north winds 40 to 50 percent of the time. The southern Great Lakes are largely affected by west or southwestern winds 30 to 40 percent of the time. In the summer months, the dominant wind directions are from the west and south.

Temperatures within the Great Lakes basin are quite variable with the northern part of the basin being colder, particularly during the winter months. The January mean temperature varies from about -2°F in the north to about 28°F in the south. The July mean temperatures vary from about 64°F north of Lake Superior to about 74°F south of the western end of Lake Erie.

There is very little seasonal variation of precipitation in the Great Lakes basin. The precipitation within the basin increases from east to west across the lakes and is generally greater in the southern reaches. The average annual precipitation north of Lake Superior is 28 inches and east of Lake Ontario is 52 inches.

Generally, winter precipitation in all areas is less than in the summer except in the snowbelt regions downwind of Lakes Superior and Huron which have 20 to 30 percent more winter precipitation than summer precipitation. Similar snowbelt areas southeast of Lakes Erie and Ontario have less predominance of winter precipitation since higher elevations and southern latitudes result in more summer rainfall over the Allegheny and Adirondack Plateaus.

The average annual snowfall can vary substantially from one year to the next. Annual snowfalls of less than 20 inches are found south of the lower lakes, while those in pockets downwind of Lakes Superior and Ontario can be as high as 140 inches.

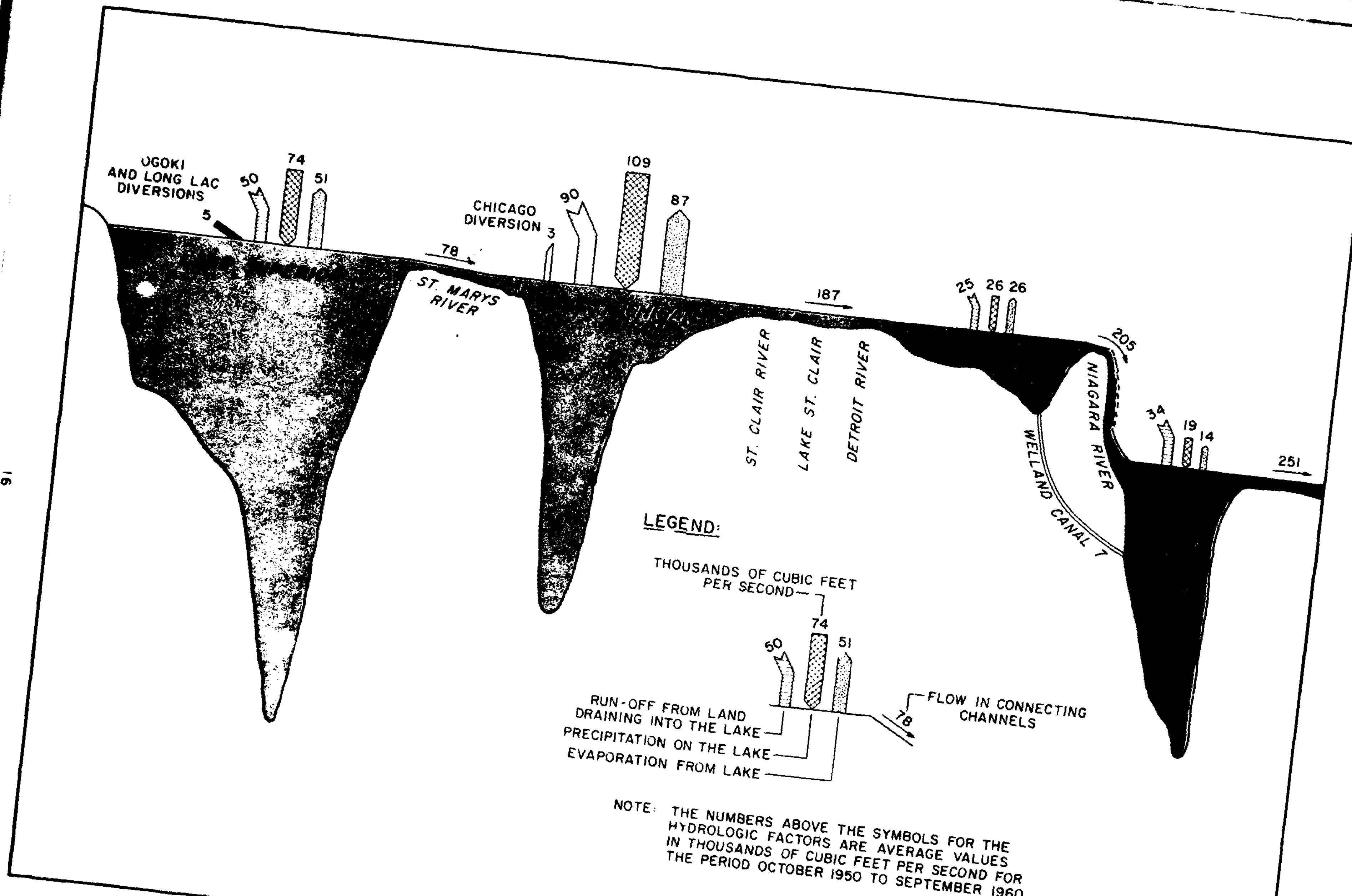
Atmospheric humidity within the Great Lakes basin is relatively high due to the influence of the lakes on evaporation and condensation. Diurnal variations in vapour pressure are small. Some change occurs within the basin with the lowest vapour pressures occurring north of Lake Superior and the highest in the southern portion of the basin.

2.2 Hydrology and Hydraulics

The levels of the Great Lakes are dependent upon the storage capacity of the lakes, outflow characteristics of the connecting channels and the St. Lawrence River, operating procedures of the regulatory structures, and the total net water supply received by each lake. The hydrologic factors influencing the total water supply received by each lake include the inflow from the upper lake, plus runoff from the land draining into that particular lake, plus precipitation falling directly on the water surface, plus any diversion into the lake (minus if out of the lake), less the evaporation from the lake's surface. Groundwater can flow into or out of the lakes. While groundwater flow is not measured directly, it was accounted for automatically by the present method of calculating supplies to the Great Lakes.

2.2.1 Hydrologic Factors

The hydrologic factors, noted above, are the dominant cause of the annual and long-term changes in the levels of the Great Lakes. They are shown graphically in their estimated proportions in Figure 4. These values are an estimated average for the period from October 1950 to September 1960 which includes both high and normal water supplies. There were no appreciable changes in the net storage from the beginning to the end of this period.



HYDROLOGIC FACTORS AFFECTING WATER SUPPLIES TO EACH OF THE GREAT LAKES

FIGURE 4

FIGURE 4

The level of each of the Great Lakes depends on the balance between the total water supplies received by that lake and its discharge to the next lower lake. If the water supplies received by the lake are greater than those discharged, its level rises. Conversely, if the water supplies are less than the discharge, the lake level drops.

Precipitation is the source of all natural water supplies to the Great Lakes. The low lake levels during the mid-1930's and 1960's were the result of persistent low precipitation for several years, while the high lake levels of the early 1950's and 1970's were caused by above average precipitation for several years. The recorded annual precipitation in the Lake Superior Basin has ranged from 24 to 40 inches, Lakes Michigan-Huron Basin from 24 to 38 inches, Lake Erie Basin from 24 to 44 inches, and in the Lake Ontario Basin from 28 to 44 inches.

Precipitation on the land surfaces moves through several stages. During freezing weather it accumulates as snow and ice. Water from snowmelt or rain either seeps into soil as temporary groundwater storage or moves over the surface as runoff to streams, swamps and lakes. The land runoff to the Great Lakes is the highest during the spring snowmelt. During the summer and fall, runoff diminishes and is sustained primarily by the release of water temporarily stored in swamps, small lakes, and the subsurface.

The annual peak runoff normally occurs in May in Lake Superior, April on Lakes Michigan-Huron, March on Lake Erie, and April on Lake Ontario. Lakes Erie and Ontario often have high runoff from their basins during the fall and winter as a result of rainfall and snowmelt occurring when land evaporation and transpiration is least and when the subsoil is either saturated or frozen. Mid-winter thaws can occur in any year and are a cause of concern with regard to flooding and ice jams in rivers and streams.

The seasonality of the hydrologic characteristics described above is reflected in the higher levels of the Great Lakes in the spring and early summer and a gradual lowering of levels during the remainder of the year. In any given year the variations from winter lows to summer highs are small, averaging about 1 foot on Lakes Superior, Michigan, and Huron, 1-1/2 feet on Lake Erie, and nearly 2 feet on Lake Ontario.

Evaporation from the land and water surfaces is dependent on solar radiation, temperature differences between the air mass and water, humidity, and wind. On the long-term average over half of the precipitation on land surfaces is lost to the atmosphere through evaporation and transpiration. When the air above the lakes is warm and moist and the lakes are cold, as in the spring, evaporation is least. In the fall and early winter, when the air above the lakes is dry and cold and the lakes are relatively warm, evaporation is the greatest.

Evaporation is always reduced considerably during periods of excessive precipitation. This is caused by a marked reduction in solar radiation and cooler temperatures due to increased cloud cover and a resulting high humidity. These hydrologic characteristics accentuate the problem of high lake levels by reducing the amount of water lost to the atmosphere during a period of high precipitation and runoff. Conversely, evaporation is greater

during drought conditions which combined with less precipitation further lowers lake levels. These natural phenomena are the dominant causes of the long-term fluctuations of the Great Lakes. The duration, magnitude, and frequency of occurrence of long-term fluctuations cannot even be predicted, much less controlled by man.

Table 2 - Monthly Net Basin Supplies for the Period 1900-1976
(Cfs-Months)

Lake	Average	Maximum	Minimum*	Range
Superior	71,000	354,000	-100,000	454,000
Michigan-Huron	110,000	496,000	-193,000	689,000
Erie	21,000	182,000	-73,000	255,000
Ontario	34,000	164,000	-22,000	186,000

*Negative values indicate that the evaporation rate from the lake surface exceeds the amount of water supplied to the lake.

Table 2 is a summary of the net basin supplies received by each lake over the period 1900-1976. Net basin supply is a term used to describe the net water supply to a lake resulting from precipitation on the lake surface, runoff from the tributary drainage area, groundwater flow into or out of the lake, and evaporation from the lake. These units are computed in cfs-months. A cfs-month is the volume of water which would accumulate at a rate of 1 cubic foot per second in 1 month.

The high water supplies to any one of the Great Lakes can only be stored temporarily. Eventually, the water is discharged to the next lower lake and augments its supply. It takes a few years for the effect of supply changes in the upper lakes to reach the lower lakes and up to 15 years for the full affect to be felt downstream.

The long-term fluctuations in the levels of the Great Lakes are the direct result of a number of years of above or below normal precipitation. Their magnitude and duration is irregular and, for this reason, high and low water levels do not occur in any regular cycles. Superimposed upon these long-term fluctuations are the inevitable annual fluctuations caused by seasonal variations in water supplies.

Meteorological disturbances such as sustained high winds or atmospheric pressure changes can cause short-term fluctuations of the water level on a lake. Such disturbances usually last from a few hours to a few days. On Lake Erie, these occurrences cause substantial localized changes in water levels due to the shallow nature of the lake. For example, sustained southwesterly winds over Lake Erie on April 6, 1979 caused the water level at Buffalo, New York, to rise more than 7 feet above the calm water level, with a corresponding lowering at Toledo, Ohio, by almost the same amount.

2.2.2 Hydraulics of the Great Lakes

In the Great Lakes system, water from Lake Superior is discharged into Lakes Michigan-Huron, that from Lakes Michigan-Huron into Lake Erie, and that from Lake Erie into Lake Ontario. Regulation of the outflow of any lake, other than Lake Ontario, affects the timing of flow into the lake immediately downstream, which in turn modifies the water supplies to the lakes situated further downstream. A profile of the system is shown on Figure 3.

The immense storage capacities (Table 3) of the upper lakes, in combination with their restricted outflow capacities, already make them a highly effective naturally-regulated water system. The effectiveness of the natural regulation is shown by the relatively small variations in levels from summer to winter and from extreme low to extreme high.

Table 3 - Volumes of the Great Lakes

Lake	Volume (cubic miles)	Percent of Total	Storage (cfs-months/ft)
Superior	2,900	54	337,800
Michigan-Huron	2,030	37	480,800
Erie	116	2	105,200
Ontario	393	7	80,000
Total	5,439	100	1,003,800

In the Great Lakes, only the outflows from Lakes Superior and Ontario are regulated, and may be varied within limits at any given water level. The outflow from Lakes Michigan-Huron is through the St. Clair and Detroit Rivers into Lake Erie, and depends on the levels of both Lakes Michigan-Huron and Erie. Lake Erie discharges through the Niagara River and Welland Canal. The major portion of the outflow from Lake Erie occurs through the Niagara River. The portion diverted to Lake Ontario through the Welland Canal is relatively small (about 4 to 5 percent of total Lake Erie outflow). Stage-discharge relationships for the uncontrolled outlet channels may be expressed in terms of lake level alone, or lake level and slope in the river.

Large variations in supplies to the lakes are absorbed and modulated to maintain outflows which are remarkably steady in comparison with the range of flows observed in other large rivers of the world. The maximum flows of these outlet rivers are only about two to three times their minimum flows. However, such stability is in marked contrast to the wide ranges of flow of several other major North American rivers; for example, the ratio of maximum to minimum flow for the Mississippi River is about 30 to 1; for the Columbia River, about 35 to 1; and for the Saskatchewan River, nearly 60 to 1.

By the nature of the Great Lakes system, the relatively steady outflow from a lake, in comparison with the fluctuating nature of the local supply to that lake, constitutes a continuous source of supply to the next lake downstream. While the local supply is an unknown variable, the storage available on a lake is a nearly predictable source of supply to the next lake downstream.

The magnitude of the reservoir effect of a lake, a significant factor in lake regulation, is much greater in Lakes Superior and Michigan-Huron than in Lakes Erie and Ontario (Table 3). This effect involves lake outlet capacity as well as lake storage capacity. Because of their larger surface areas, the levels of Lakes Superior and Michigan-Huron respond much more slowly, than do the levels of Lakes Erie and Ontario, to changes in outflow of the same magnitude. On the basis of difference in surface areas only, regulation of the levels of Lakes Superior and Michigan-Huron would require a greater range of outflow for a given lake level range than is required in the case for Lakes Erie and Ontario, in order to obtain a comparable degree of lake level stabilization.

Because of the size of the Great Lakes and the limited discharge capacities of their outflow rivers, extremely high or low levels and flows persist for some considerable time after the factors which caused them have changed. Some measure of the importance of this may be gauged from the fact that it takes 2-1/2 years for only half of the full effect of a continuous supply change to Lakes Michigan-Huron to be realized in the outflows from Lake Erie.

2.3 Population

2.3.1 United States Population Projections

The population projection series of the United States Great Lakes region used for this study was the 1972 Office of Business Economics - Economic Research Service (OBERS) Series "E" projections of economic activity in the United States.

The OBERS projections, like all other projections, are conditional forecasts of the future. Projections are based on an extension of past relationships believed to have future relevance for the measures being projected. The projections represent estimates of economic activity expected to develop during the projection period if all assumed conditions materialize. For example, the Series "E" projection assumes a birth rate which will eventually result in no further population growth, except for immigration.

The population projections presented in Table 4 are for each of the Great Lakes States. All of these States show very moderate growth rates during the period 1970 to 2020.

Table 4 - Great Lakes State Population Projections

	1970	1980	1990	2000	2010 1/	2020
United States	203,200,000	223,500,000	246,000,000	263,800,000	281,400,000	297,100,000
New York	18,260,000	19,350,000	20,950,000	22,440,000	23,930,000	25,220,000
Pennsylvania	11,880,000	12,650,000	13,420,000	13,990,000	14,560,000	15,100,000
Ohio	10,690,000	11,650,000	12,610,000	13,380,000	14,150,000	14,770,000
Michigan	8,900,000	9,740,000	10,650,000	11,340,000	12,030,000	12,490,000
Illinois	11,140,000	12,090,000	13,060,000	13,880,000	14,700,000	15,380,000
Indiana	5,210,000	5,780,000	6,360,000	6,840,000	7,320,000	7,710,000
Wisconsin	4,430,000	4,740,000	5,010,000	5,230,000	5,450,000	5,630,000
Minnesota	3,820,000	4,120,000	4,550,000	4,900,000	5,250,000	5,500,000
Total	74,330,000	80,120,000	86,610,000	92,000,000	97,390,000	101,800,000

1/ year 2010 data was based on interpolation of year 2000 and 2020 data.

SOURCE: 1972 OBERS projections: Economic activity in the U. S. Series E Population, Volume 4 states, Water Resource Council.

2.3.2 Canadian Population Projections

The Canadian portion of the Great Lakes basin contained one-third of the total population of Canada in 1971. Similarly, it produced almost one-third of the country's national income.

The population forecasts in Table 5 were done by the Regional Planning Branch of the Ontario Ministry of Treasury, Economics, and Intergovernmental Affairs and are presented in terms of Great Lakes sub-basins (Figure 5). A basic assumption underlying these forecasts is that there will be no major intervention in current trends, in the form of development projects or special government policies.

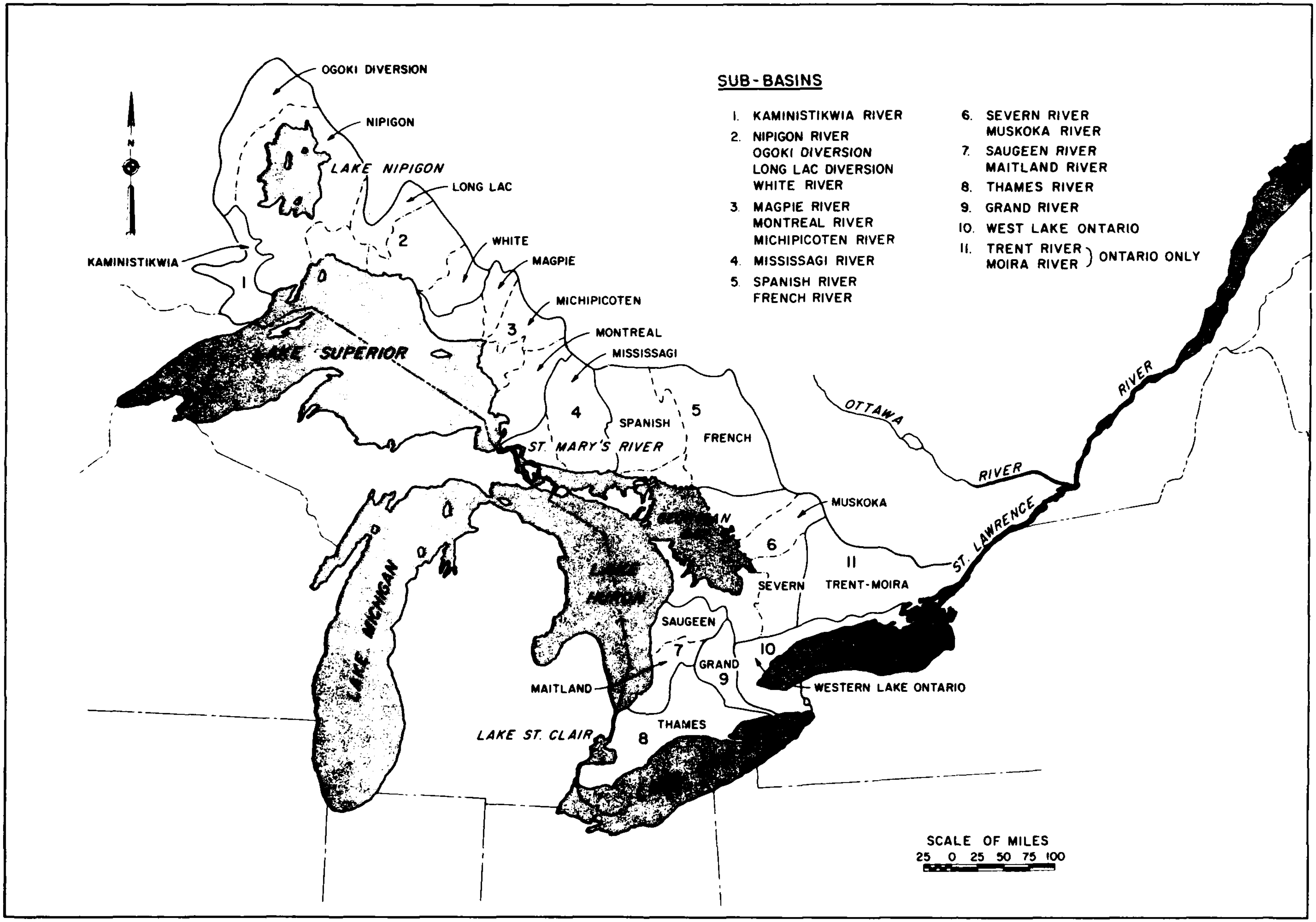
Table 5 - Canadian Great Lakes Basin
Population Projections

Sub-basin	1971	1981	2011	2021
Lake Superior				
Kaministikwia	115,294	121,578	130,386	137,337
Nipigon-White	26,280	27,808	30,051	31,894
Magpie-Michipicoten-Montreal	6,340	7,316	9,383	11,794
Lake Huron				
Mississagi	101,272	116,863	149,881	188,393
Spanish-French	267,583	321,688	433,902	573,991
Severn-Muskoka	401,934	464,427	599,792	763,349
Saugeen-Maitland	166,980	176,177	198,517	226,604
Lake Erie				
Thames	1,021,639	1,157,109	1,411,939	1,649,313
Grand	493,806	596,506	862,758	1,192,141
Lake Ontario				
Western Lake Ontario	3,656,181	4,294,572	5,821,387	7,567,111
Trent-Moira	378,883	412,432	482,620	551,578
Total	6,636,192	7,696,476	10,130,616	12,893,505

The total population of the Canadian Great Lakes basin is predicted to almost double over the 50-year period from 6.6 million in 1971 to 12.9 million in 2021.

2.4 Environmental Conditions

The Great Lakes basin is of high economic and social value. Human activity in the basin has grown immensely since the days of the early settlers. In particular, urban, industrial, and commercial development in the nearshore area has been very active. Much of that development and related activity has relied heavily upon the basin's natural assets, in particular, for water, fish, and wildlife.



CANADIAN GREAT LAKES RIVER BASINS

FIGURE 5

FIGURE 5

As a result of cumulative developments, only a small portion of the Great Lakes coastal zones remain in their natural state and the quality of the water environment, including the fauna and flora which it sustains, has changed dramatically, especially on Lake Erie. Fortunately, it was recognized some years ago that the resources of the Great Lakes and their coastal zone are not infinite. The growing demands made upon them resulted in degradation of these valuable natural environments, and the Governments signed a water quality agreement in 1972 (later expanded in 1978) to rectify the situation.

Changes in the water level regime of the lower Great Lakes, due to regulation, could impact upon water quality, wildlife, and fish. The construction and operation of the Niagara River regulatory works would probably also affect these resources.

The environmental evaluation was generally based on an analysis of existing information, with respect to three disciplinary areas: water quality, wildlife resources including wetlands, and fish. While the existing baseline data are generally adequate for describing the existing conditions for the purposes of a preliminary analysis, they are not at a sufficient level of detail to permit in-depth analysis. In the case of fish and wildlife, for example, habitat description to the 6-inch contour interval would be necessary to conduct a sound, detailed environmental analysis.

2.4.1 Water Quality

The maintenance of good water quality in the Great Lakes is essential for many social and environmental interests. Freedom from nuisance algae, bacteria, and turbidity (the degree of water clarity) are important to the aesthetic appeal and property value of the shore, and to such recreational activities as swimming and boating. The amount and kind of water treatment which must be provided by industries and municipalities dependent upon the Great Lakes for water supply is also affected by water clarity. Freedom from toxic effects and the strict limitation of nutrient inputs to the lakes are imperative in maintaining and/or enhancing the integrity of the existing ecosystem of the Great Lakes.

In recent decades, however, numerous water quality problems have developed as a result of various human activities some of which were not recognized, at the time, as being incompatible with the objectives of maintaining good water quality. While Lake Ontario, as a whole, is generally considered to be mesotrophic, Lake Erie is experiencing problems of eutrophication. A eutrophic condition is an undesirable nutrient-rich state resulting in overproduction of aquatic plants, thereby diminishing suitable habitat for preferred fish and wildlife species. A mesotrophic condition is one of intermediate fertility; neither notably high nor low (oligotrophic) in productivity. The hypolimnion (water layer near lake bottom) of the central basin of Lake Erie has been experiencing states of anoxia (low oxygen levels) during the summer; a condition which is deleterious to fish, especially the cold water species which require the hypolimnion refuge to satisfy metabolic temperature requirements. Growth of Cladophora, a nuisance alga, occurs over much of the shoreline of both Lakes Erie and Ontario, contributing to the

degradation of shoreline aesthetics and property values. The problems related to nutrient overenrichment can be attributed largely to the discharge of phosphorus into the Great Lakes as a result of activities (both rural and urban) throughout the basin.

The releases of various toxic chemicals from agricultural and industrial sources to the Great Lakes has become a major concern. PCB's, DDT, mercury, and mirex have been found in lake sediments, fish, herring gulls, and even man. However, these substances were not determined to be dangerous to the welfare of the ecosystem until they had become rather pervasive in their distribution. As a result, the integrity of the ecosystem, and human health as a consequence, are being threatened. In the past decade regulatory agencies have restricted and sometimes banned the use of a number of persistent and toxic substances, including mercury, mirex, PCB, and DDT. Fishing for certain commercial and sport species has also been restricted in specific areas of the lower Great Lakes, particularly Lakes St. Clair and Erie, due to the excessive bioaccumulation of persistent toxicants in fish.

Due to the natural capacity of the finer fractions of sediments (e.g., clays) for adsorbing many of the toxicants and nutrients, dredging and landfill operations in the Great Lakes have received considerable attention from both the public and private sectors. These operations, particularly in navigation channels, are responsible for the resuspension of the associated pollutants, thus engendering water quality problems in both the areas dredged and farther downstream.

More specifically, 24 local problem areas have been identified on Lake Erie and 15 on Lake Ontario by the International Joint Commission. For example, the Detroit River is suffering from bacteria, phenols, and iron problems; the Ashtabula River is hampered by chemical pollution emanating from Fields Brook Tributary; the Niagara River has problems related to nutrients, phenols, bacteria, and certain persistent toxicants and Hamilton Harbour continues to have oxygen depletion maladies.

Efforts are being made under the United States - Canada Great Lakes Water Quality Agreements to maintain and enhance the water quality of the Great Lakes. Results of recent studies of water quality show reductions in the levels of DDT and mercury in Lake Erie. Studies of herring gulls have also exhibited decreased PCB, DDT, and mirex levels since 1975, reflecting progress from the effort to eliminate these compounds from the ecosystem, through the implementation of appropriate remedial programs. Additionally, the total input of phosphorus, which is regarded as a primary agent in the eutrophication of the Great Lakes, has been reduced substantially in both Lakes Erie and Ontario. While open-lake total phosphorus concentrations have not changed in Lake Erie, data for Lake Ontario indicate a 15 to 20 percent lakewide decrease between 1977 and 1978. Statistically significant reductions in the order of 35 percent have also been noted in the nearshore areas of Lake Ontario near Toronto, Ontario.

2.4.2 Wildlife

Four species of mammals, over 20 species of reptiles, and over 100 species of birds depend on the wetlands, beaches, shoals, or open-water of the Great Lakes for survival, and many other species prefer wetland habitats. The regulation plans investigated would not noticeably alter the value of the deep, open waters of the lakes and interconnecting channels to wildlife species.

Wetlands are the highest quality and the most valuable wildlife habitat along the shorelines of the lower Great Lakes. Wetlands, considered as one of the most biologically productive ecosystems and supporting a great diversity of plant and animal populations, are defined as:

> "land where the water table is at, near or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes" (Cowardin et al., 1977).

Wetlands provide essential habitat for a wide variety of wildlife species. They are essential to waterfowl that use them for staging, nesting, and brood rearing. Some of the best staging locations for waterfowl in eastern North America include the St. Clair Flats at the north end of Lake St. Clair, the marshes of western Lake Erie and the lower Detroit River, Long Point on Lake Erie, the marshes of eastern Lake Ontario and sections of the St. Lawrence River including the wetlands of Lake St. Francis, the interconnecting channels of Les Iles de la Paix, Lake St. Louis, the Boucherville/Delta Sorel Reach, and Lake St. Peter.

Migratory birds such as herons, bitterns, rails and shorebirds, are dependent upon wetland habitat during at least one season of the year. Wetlands provide habitat for water-oriented mammals (e.g., muskrats and otters), reptiles (e.g., snakes and turtles), amphibians (e.g., frogs and salamanders), and invertebrates (e.g., insects and molluscs).

Some species of wildlife are classed as rare, endangered, or threatened and have a limited distribution, part of which includes wetlands of the lower Great Lakes. The Bald Eagle, Eastern Fox Snake, Spotted Turtle, Fowler's Toad, and Lake Erie Water Snake are a few of these species.

Wetlands provide recreational opportunities for the public through fishing, hunting, and birdwatching. They also support economically important fur, fishing, and recreational industries. In addition, wetlands provide an aesthetic value of flora, fauna, and open space.

Wetlands are recognized as having significance beyond their value as wildlife habitat and recreational areas. Water quality may be improved through the trapping of suspended sediments and the filtering of pollutants. Wetlands also act as natural buffer zones along the lakeshore, to absorb and dissipate wave energy and thereby reduce shore erosion.

Wetlands of the Great Lakes are exposed to variations in water levels caused by: long-term climatic cycles, short-term climatic occurrences, the annual fluctuation of water levels, seiches, and, wave action. The present productive state of wetlands has been attained in association with these historic water level fluctuations. The extreme levels associated with the above phenomena maintain the stability of the wetlands. The periodic disturbances (i.e., flooding and drying) interrupt plant succession, preventing the formation of dense beds of emergent vegetation, and promoting interspersion of vegetation and water. They also result in the periodic release of nutrients to the wetland, thereby promoting renewed plant vigour and increasing invertebrate populations essential to wetland wildlife. The end result of such periodic disturbances is greater species diversity, both of vegetation and wildlife. Fluctuating water levels are essential to continue to make the wetlands of the lower Great Lakes attractive to wildlife.

Shoreline wetlands of the lower Great Lakes were inventoried from maps and aerial photographs according to a classification scheme designed for this study. Definitions of the seven wetland types are based mainly on the physiographic features of the wetland (Table 6). In general, wetland types 1 through 4 are hydrologically defined as lake supported, whereas types 5 through 7 are only partially lake supported. The seven types represent wetland situations ranging from completely open to lake effects (1) to completely protected (7). The wetland inventory indicated that 151,760 acres of wetland exist along the shorelines of the lower Great Lakes (Table 6).

Wetlands are and will continue to be under pressure from residential and industrial development, from recreational development such as marinas, and from agricultural interests. The alteration of the Great Lakes water regime could place these wetlands under an additional pressure, and probably reduce their value to wildlife species.

2.4.3 Fish

The lower Great Lakes and connecting channels support over 100 species of native and exotic fish, making it one of the most significant freshwater resources of North America. As many as 30 species are of major commercial importance, while some are classified as game fish. In Lake Erie, yellow perch, white bass, rainbow smelt, walleye, and channel catfish are the most commercially important species. In Lake Ontario, eels, yellow perch, white perch, and bullheads are some of the most commercially important species. The bass and salmonid sport fishery in both lakes and in the connecting waters should be noted as should the northern pike and muskellunge in the connecting waters (i.e., St. Clair River, Lake St. Clair, Niagara River, and St. Lawrence River).

Fish and fishing-related activities are of importance to the lower Great Lakes communities. This importance is indicated, in part, by the value of the U.S. commercially landed Lake Erie catch which exceeded $12.2 million in 1978. The Lake Ontario 1978 commercial harvest had a total dockside value of approximately $1.4 million.

Table 6 - Wetland Area of the Lower Great Lakes by Wetland Type
(Acres)

	1. Open Shoreline	2. Unrestricted Bay	3. Shallow Sloping Beach	4. River Delta	5. Restricted Riverine	6. Lake-Connected Inland	7. Protected	Total
ST. CLAIR RIVER								
Canada	221					15		236
United States								
Total	221					15		236
LAKE ST. CLAIR								
Canada	2,788			16,824	28		12,563	32,203
United States	125			5,848	56	298	3,805	10,132
Total	2,913			22,672	84	298	16,368	42,335
DETROIT RIVER								
Canada	600	123			98		633	1,454
United States	125	135						260
Total	725	258			98		633	1,714
LAKE ERIE								
Canada	516	141	18,195		2,313	5,221	2,637	29,023
United States	2,005	1,618	374		1,569	510	18,236	24,312
Total	2,521	1,759	18,569		3,882	5,731	20,873	53,335
NIAGARA RIVER								
Canada								
United States	57	12				197	26	292
Total	57	12				197	26	292
LAKE ONTARIO								
Canada	1,114	6,353	534		6,035	4,484	590	19,110
United States	280	1,721		90	919	4,401	5,901	13,312
Total	1,394	8,074	534	90	6,954	8,885	6,491	32,422
ST. LAWRENCE RIVER								
Canada (Ont.)	6,910	3,965			1,917	1,333	23	14,148
United States	1,029	1,357			1,609	2,828	455	7,278
Total	7,939	5,322			3,526	4,161	478	21,426
TOTALS								
Canada	12,149	10,582	18,729	16,824	10,391	11,053	16,446	96,174
United States	3,621	4,843	374	5,938	4,153	8,234	28,423	55,586
Total	15,770	15,425	19,103	22,762	14,544	19,287	44,869	151,760

The combined U. S. and Canadian commercial fishing industry annually harvests an average of 50 million pounds of fish from Lake Erie and another 2.5 million pounds from Lake Ontario which represents more than one-third of the total annual Great Lakes harvest. In Lake Erie, the perch and smelt are the mainstay of the commercial fishery. However, white bass and gizzard shad are increasing in importance, and significant numbers of bullhead, carp, catfish, and sunfish are also harvested. The commercial fishery of Lake Ontario is centered around the shallow and productive eastern basin and the St. Lawrence River. In those waters, yellow perch, white perch, eel, and carp are the principal commercial species.

The sport fishing industry in the lower Great Lakes is now a multimillion dollar business. The value of the recreational fishery was estimated at $60 million in 1978 for the Ohio waters of Lake Erie alone. The Province of Ontario reported 562,000 angler-hours in 1978 for Lake Erie. The total 1978 economic impact of all fishing-related activities (commercial and sport) for Lake Erie exceeded $250 million. Sport fishing on Lake Ontario and the St. Lawrence River is also very important. In the St. Lawrence River, a great portion of the area's economy is linked to the sport fishing industry.

Traditionally, nearshore warm and cool water fish - such as bass (both largemouth and smallmouth), northern pike, perch, walleye (yellow pickerel), and muskellunge have been the species most sought after by anglers. However, recent introductions of exotic and hybrid coldwater species have sparked a new interest in offshore recreational fishing.

The shallow water environments are the most biologically productive areas of the system. These areas provide important spawning, nursery, and feeding grounds which are essential to the maintenance of the fish stocks. Some of the more important shallow water areas are Lake St. Clair, Lake Erie's western basin, and Long Point Bay, the eastern basin of Lake Ontario, and the St. Lawrence River.

The importance of the Great Lakes wetlands as fish habitat and detrital producers has been realized but not quantified. Naturally fluctuating water levels rejuvenate coastal wetlands so that they do not "age" like inland wetlands. Artificial regulation of water levels could impact the fish populations through the alteration of habitat and/or stress placed on a segment of the food chain, or by allowing the wetlands to "age."

In the past, culturally induced environmental changes have had considerable effects on the fish stocks of the system. Degradation and loss of spawning grounds have had major detrimental impacts with nutrient loading, contaminants, and over-exploitation, further stressing the stocks. The specific effects that regulation of lake levels would have on fish stocks are largely unknown. There is a particular lack of information on the nearshore area concerning the way in which fluctuating water levels affect fish utilizing this very productive zone. The impact of limited regulation is impossible to quantify without detailed habitat contour mapping of the nearshore area both above and below the water line.

2.5 Coastal Zone

The total length of Great Lakes-St. Lawrence River System shoreline, including islands, measured to Trois Rivieres, Quebec, is approximately 12,100 miles (Table 7). In the United States, there are 5,270 miles of shoreline in eight States and in Canada, 6,850 miles of shoreline in the Provinces of Ontario and Quebec. The shoreline characteristics range from extremely flat lowland areas highly susceptible to flooding (such as the St. Clair Flats on Lake St. Clair), to high bluff areas some of which are highly erodible till (such as in southern Lake Michigan along the Michigan shore and the north central shore of Lake Erie), to impregnable rocky bluffs (such as are typical along the shore of Lake Superior).

Table 7 - Great Lakes Shoreline Lengths

	Canada		United States	
	Mainland (mi)	Islands (mi)	Mainland (mi)	Islands (mi)
Lake Superior	866	615	863	382
St. Marys River	66	63	29	89
Lake Michigan	0	0	1,400	238
Lake Huron	1,270	1,720	580	257
St. Clair River	30	5	28	0
Lake St. Clair	71	43	59	84
Detroit River	30	33	30	39
Lake Erie	368	29	431	43
Niagara River	33	3	36	34
Lake Ontario	334	50	300	28
St. Lawrence River, from Lake Ontario to Trois Rivieres, Quebec	595	623	160	164

2.5.1 Economic Activity

The Great Lakes basin economy is industrially based utilizing the transportation and power advantages offered by the Great Lakes-St. Lawrence system. In addition, there is significant agricultural, mining and forestry production. While the entire basin is affected by the levels of the Great

Lakes, the coastal zone is most directly impacted by fluctuating lake levels. The coastal zone contains valuable land which has been developed by many diverse and sometimes conflicting interests. A principal use of coastal land is industrial development, including steam and hydropower generating plants, which require large amounts of water.

Another important use of coastal land is residential, both permanent and seasonal. It is within this usage category that most damage from storms is inflicted due either to a lack or failure of protective works to accomplish their intended purpose in areas susceptible to erosion and/or flooding. A third use of the coastal zone is for public and private recreational facilities. Parks, beaches, boating facilities, forest preserves, and other types of recreational developments abound along the shoreline. Recreational boating facilities are sensitive to fluctuations in lake levels; docks and ancillary structures may be flooded or left with insufficient water depth, preventing normal usage.

Much of the land in the basin can accommodate only restricted uses. Availability for any particular use is determined by the characteristics of the shore type and by the current uses of the specific area and the adjacent land.

2.5.2 Areas of Concern

In the International Joint Commission's report to the Governments of Canada and the United States, "Further Regulation of the Great Lakes," 1976, one of the recommendations was that the appropriate authorities act to institute land-use zoning and structural setback requirements so as to reduce future Great Lakes shoreline damage. The Canadian and Ontario Governments have issued flood and erosion hazard maps which delineate hazard areas in the coastal zone based on long-term erosion rates and flood mapping. In addition, flood damage reduction programs which restrict development in hazardous shore areas are in effect in both Ontario and Quebec. The United States has instituted a Coastal Zone Management Program which is administered by the individual States as well as a Flood Insurance Administration Program. Even with these programs, however, there is concern that further development may continue in many of the damage prone areas of the coastal zone.

During the period September 1972 to September 1976, Lakes Michigan-Huron, St. Clair, and Erie reached historic high water levels. In an effort to determine the economic impact of water levels on damage to the shoreline, the U. S. Army Corps of Engineers conducted an extensive damage survey covering the entire U. S. shoreline. The results indicate that for that period of time there was in excess of $376 million in damages and costs of protective works directly attributable to the effects of erosion and inundation along the coastal zone. During the period of high water, the U. S. Army Corps of Engineers spent over $27 million in advanced temporary flood protection measures on privately-owned properties which prevented an estimated additional $132 million in damages (damages and costs are in 1975 dollars).

In Canada, along the shoreline in the Province of Ontario, severe damages occurred during the period November 1972 to November 1973. A comprehensive survey performed by the Federal and Provincial Governments estimated total damages for the one year period to be almost $17 million in 1973. The damages to shore property and lost land value for the Province of Ontario shore of each lake are presented in Table 8.

Table 8 - Ontario Shore Damages,
November 1972 - November 1973
(1973 $)

	$000's
Ontario	4,424
Erie	5,496
St. Clair	5,598
Huron	1,359
Superior	-
Total	16,877

NOTE: No survey was carried out on Lake Superior.
SOURCE: Adjusted Canada-Ontario Great Lakes Shore Damage Survey, Technical Report, 1975.

The Quebec portion of the St. Lawrence River suffered severe damages in both 1974 and 1976. A compensation program was carried out in both instances. Total assistance and flood fighting costs were $5,274,000 in 1974 and $9,191,000 in 1976. However, these figures only represent a portion of the actual damages, since the assistance programs involved exclusion of some damages, upper limits for other damages, and deductible amounts.

Presented below is a summary of the existing shoreline use and problem areas which would be most affected by further regulation of the lake water levels.

2.5.3 Land Use - United States Shoreline

Land use information in the coastal zone, for the U. S. portion of the Great Lakes Basin as compiled under contract to this study by the Great Lakes Basin Commission (GLBC) in 1976 through 1978 is presented in Table 9, summarized by lake.

As part of this work, the GLBC compiled the projected land-use by county, based upon the best available information. The general trend along the coastal zone appears to be a slow increase in population. As the Coastal

Table 9 - United States Land-Use by Lake

Lake	Shoreline Length (mile)	Percent										
		Inland Water	Wetland	Forest	Brushland	Grassland	Barren	Plowed	Total Urban* Residential	High Density Residential	Low Density Residential	Commercial
Superior [a]	892	2.7	8.0	62.1	4.5	1.1	5.6	0.5	15.6	1.4	14.0	0.2
Michigan	1,400	0.9	5.9	35.8	8.0	5.6	1.3	5.6	36.9	7.1	25.3	4.5
Huron	580	3.7	7.5	31.6	9.6	4.1	0.0	7.4	36.1	9.0	27.0	0.2
St. Clair [b]	117	1.0	9.8	4.2	4.4	1.2	0.0	5.8	73.6	24.4	22.5	26.7
Erie	431	0.4	6.7	10.6	9.0	4.8	1.0	9.7	57.8	23.4	21.7	12.7
Ontario [c]	336	3.3	2.8	24.4	14.0	7.8	0.1	5.2	42.4	5.7	36.3	0.4
Great Lakes System**	3,756	2.0	6.8	28.1	8.2	4.2	1.3	5.8	43.6	11.8	24.5	7.3

a - Includes St. Marys River
b - Includes St. Clair River, Lake St. Clair, and Detroit River
c - Includes Niagara River
* - Total Urban Residential is the total of High Density Residential, Low Density Residential, and Commercial classes.
** - Excluding St. Lawrence River Basin

SOURCE: Great Lakes Basin Commission, Summary of Existing and Projected Land Use Information for the Great Lakes Coastal Counties, Contract No. W74 RDV 78290 005 for U. S. Army Engineers, November 1978

Zone Management Programs become further developed and implemented, the rate of additional development in the coastal zone will decrease. It is estimated that coastal shoreline development during the next 20 to 50 years will increase in the U. S. from 10 to 30 percent in many areas throughout the Great Lakes.

Land use controls and setback requirements have been enacted in some States and are planned in others. Potentially, these could aleviate some future damages by preventing development in areas which are hazardous.

2.5.4 Land Use - Canadian Shoreline

As part of the Canada-Ontario Great Lakes Shore Damage Survey, the land-use of the Canadian shoreline was tabulated from Port Severn, Ontario, on Lake Huron, through Lakes Erie and Ontario to Cornwall, Ontario, on the St. Lawrence River. For the shore of Lake Superior and the remainder of Lake Huron, land-use data from the International Great Lakes Levels Board Study remain applicable and were used. The St. Lawrence Study Committee collected land-use information for the International Section of the St. Lawrence River. This information is presented in Tables 10 and 11.

Table 10 - Land-Use Along the Province of Ontario Shoreline (Miles)

	Superior*	Huron*	St. Clair	Erie	Ontario (to Cornwall)
Residential	12	244	35	164	269
Commercial & Industrial	106	169	5	8	34
Agricultural & Forest	1,250	2,169	33	145	422
Other		25	4	19	24
Recreational & Public Land	131	525	43	62	307

* Approximate

Land use controls and setback requirements are being implemented in Ontario. It is expected that the effectiveness of these controls will prevent significant additional development in hazardous areas.

Table 11 - Land-Use, Cornwall, Ontario-Trois Rivieres, Quebec Shore (Miles)

Urban	320
Industrial	30
Roads	70
Agricultural	210
Forest	250

2.5.5 Problem Areas

United States: The highest proportion of damages were on Lakes Erie and Michigan, with $119 million and $91 million total damages and cost of protection, respectively. These two lakes account for almost 60 percent of all damages. Lake Erie shore is essentially erodible bluff with low-lying floodprone areas on the western end of the lake and with extensive development along much of the entire shore. It is this development, along with the shore characteristics and storm severity which make Lake Erie so prone to damages. Lake Michigan has a much greater variation in shore characteristics with a higher level of undeveloped and forested land. One reason for the higher damages on Lake Michigan is that its shore is relatively long.

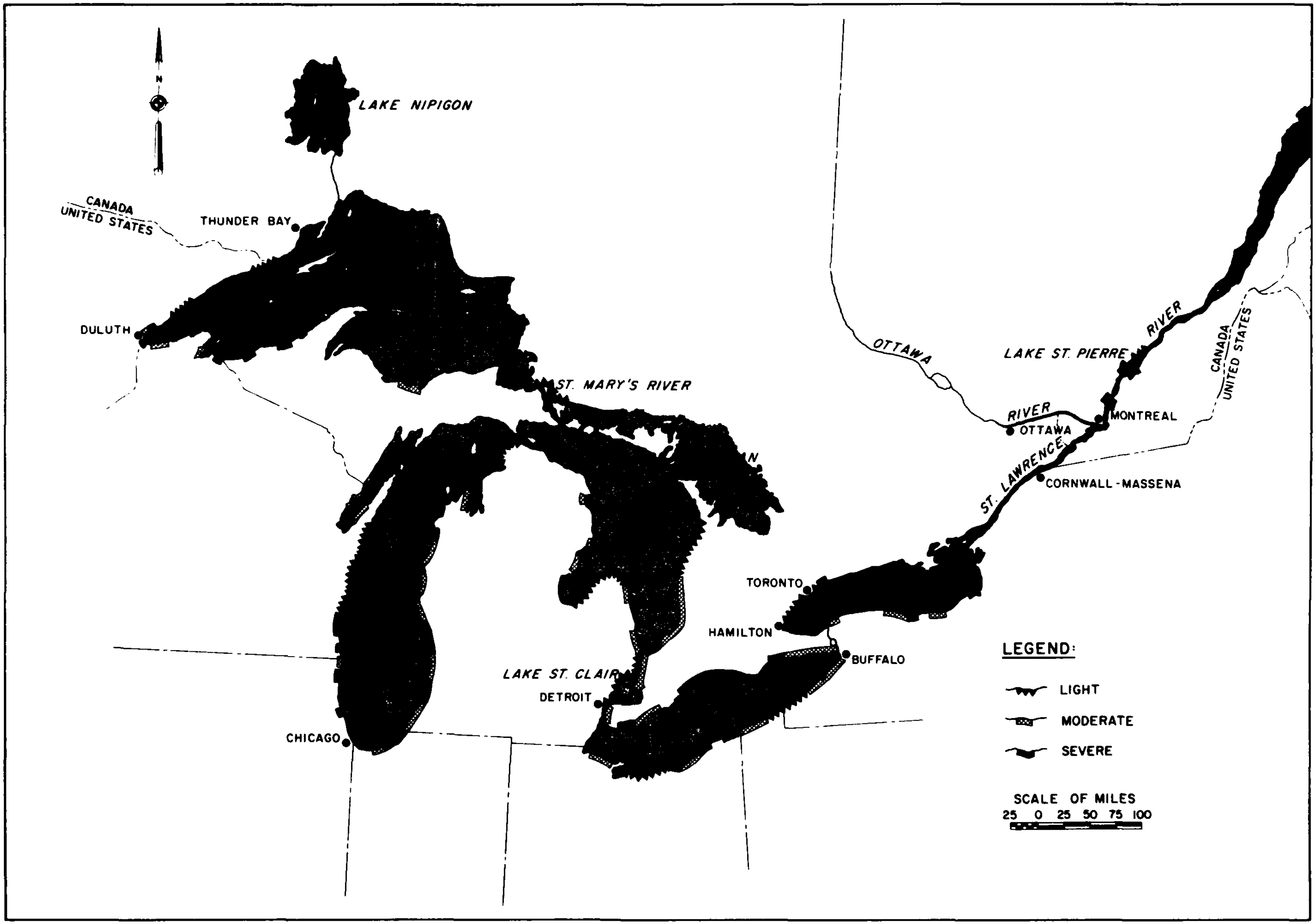
Figure 6 shows the areas most affected by erosion and the degree of severity along the Great Lakes shoreline. Figure 7 shows the major areas which are affected by flooding along the Great Lakes-St. Lawrence River shoreline.

Canada: Areas of the Canadian shoreline that are affected by erosion are shown in Figure 6. The most severe problems are on eastern Lake Ontario, much of Lake Erie, and southern Lake Huron. These areas are mainly erodible bluff, with much of the Ontario and Huron shoreline being heavily developed.

Areas that suffer moderate to severe flood problems are shown in Figure 7. The Montreal area and the south shore of Lake St. Clair suffer the most severe damages. Both of these areas have extensive development along the shore.

2.6 Power Development

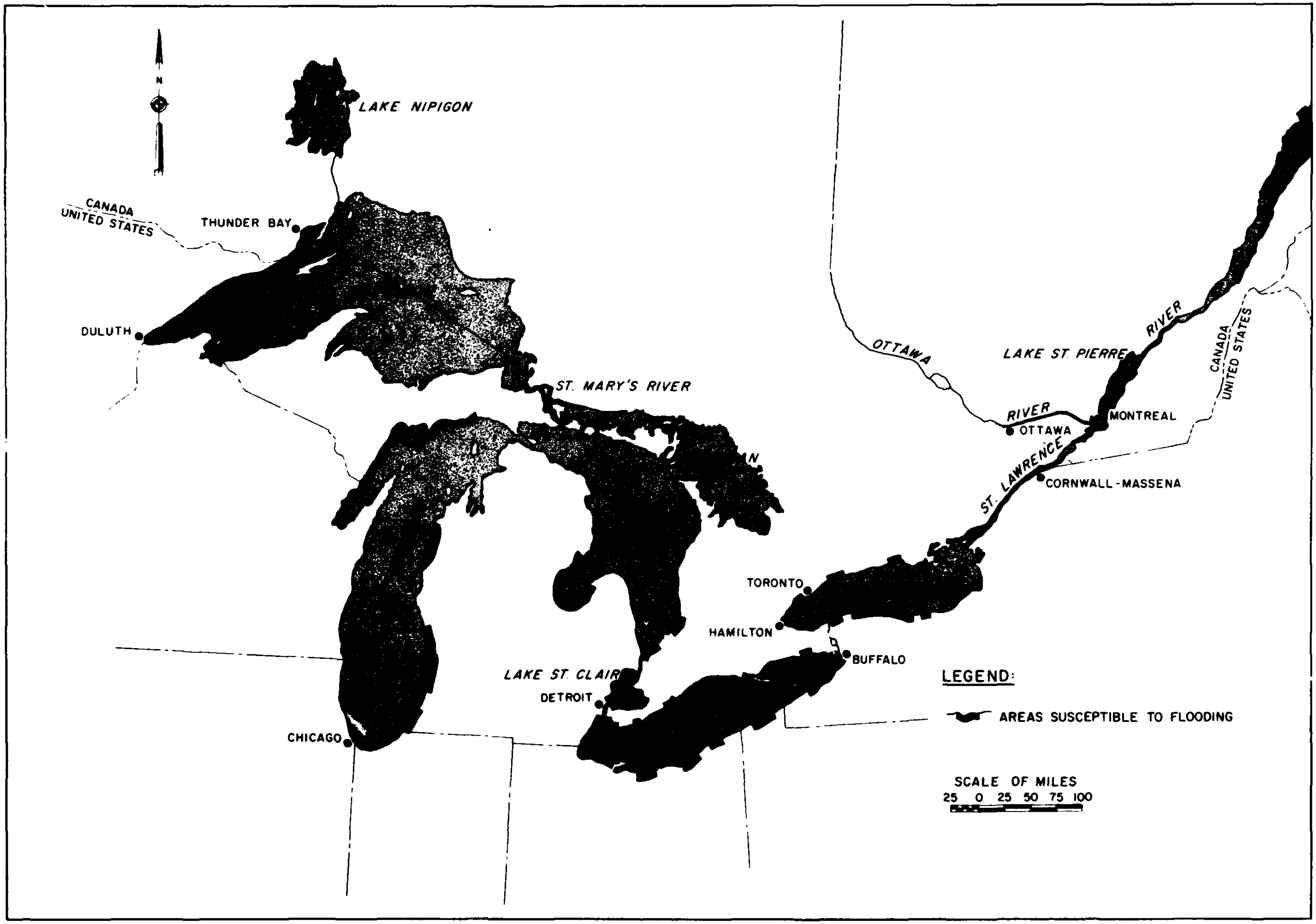
The existing (1979) hydroelectric installations affected by regulation of the Great Lakes have a total installed capacity of 7,989,300 kW of which 4,827,700 kW are in Canada and 3,161,600 kW are in the United States. Since the unit cost of power generated at these Great Lakes hydroelectric installations is cheaper than power produced from thermal installations (oil, fossil, or nuclear fueled), maximum utilization of the hydroelectric power capacity is economically and environmentally desirable.



GREAT LAKES - ST. LAWRENCE RIVER SHORELINE SUBJECT TO EROSION

FIGURE 6

FIGURE 6



GREAT LAKES - ST. LAWRENCE RIVER SHORELINE SUBJECT TO FLOODING

FIGURE 7

FIGURE 7

2.6.1 St. Lawrence River Plants

Beauharnois-Cedars Power Plants: Quebec Hydro's Beauharnois-Cedars developments are in that part of the St. Lawrence River referred to as the Soulanges Section (Figure 8). This comprises the 15-mile stretch between Lake St. Francis and Lake St. Louis in which there is a total drop of 82 feet. The drop occurs in three series of rapids separated by intervening pools of smooth water. At the outlet of Lake St. Francis are the Coteau Rapids which extend 1 mile and fall 20 feet into a 4-mile stretch of smooth water reaching to the head of Cedars Rapids. Over the next 2 miles, the Cedars Rapids fall 35 feet into a smooth section which flows 4 miles to the Cascades Rapids which discharge into Lake St. Louis, a fall of 27 feet.

To harness the energy of the water in this turbulent reach, control dams were constructed at the exit from Lake St. Francis to allow the flow to be diverted from the natural channel into a canal excavated on the south shore called the Beauharnois Power and Navigation Canal. The canal is 15 miles long and 3,300 feet wide, and the average depth is more than 30 feet. The navigation channel which is 500 feet wide and has a minimum depth of 27 feet is located along the north bank of the canal.

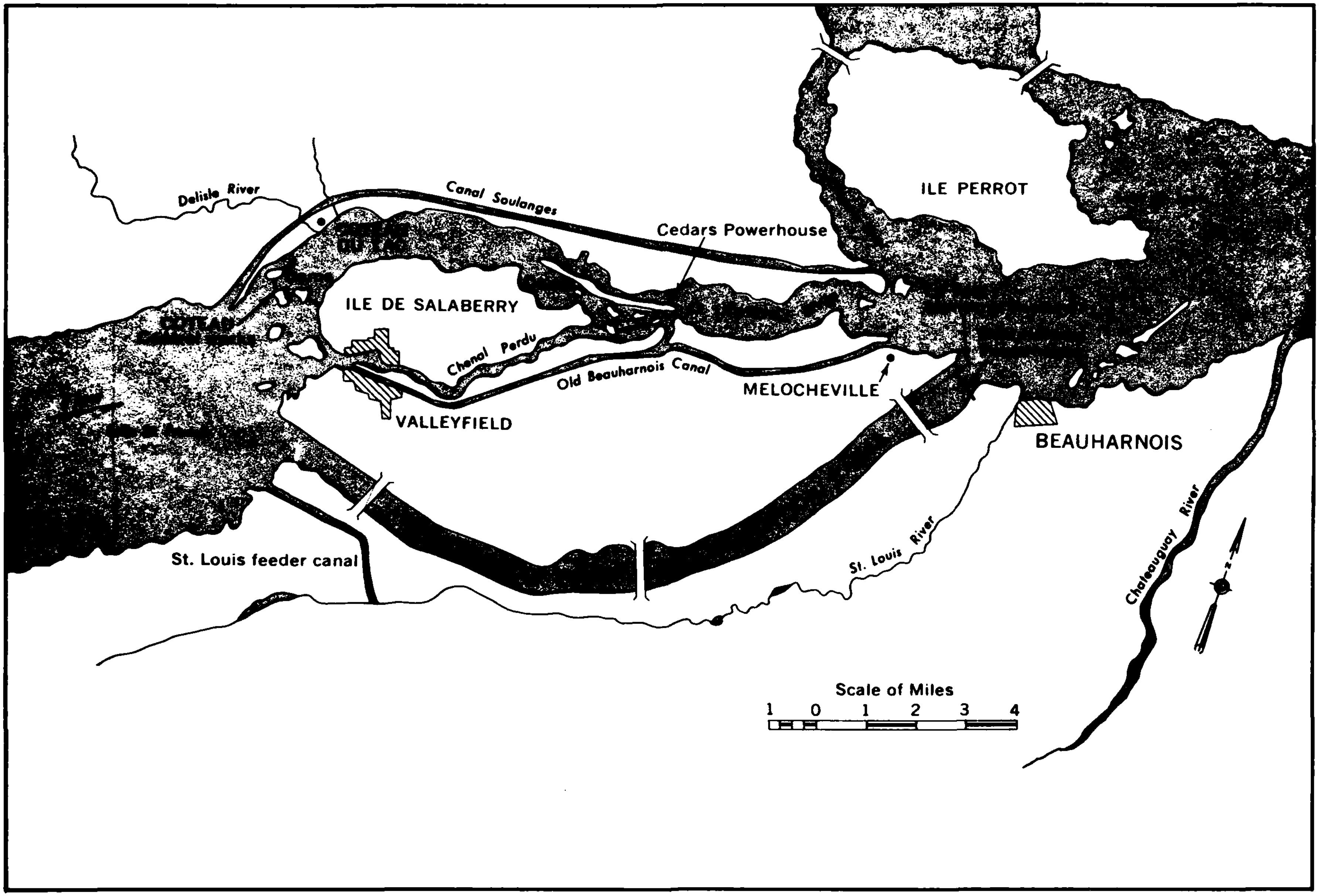
After passing through the Beauharnois Canal and the 80-foot drop at the Beauharnois Powerhouse, situated at the outlet end of the canal, the water is discharged into Lake St. Louis. Two tandem locks permit navigation to pass from the canal to Lake St. Louis.

The Beauharnois Powerhouse has 36 turbines for a total capacity of 1,574,000 kilowatts, excluding two auxiliary units.

The Cedars Generating Station came into service in 1914 with a capacity of 81,000 kilowatts from nine units. Other units were added as required until the plant reached its present capacity of 162,000 kilowatts from 18 units in 1924.

Moses-Saunders Power Plants: In 1952, the Commission issued an order approving applications by the United States and Canada for the joint construction, maintenance and operation of a power project on the St. Lawrence River. The order specified, among other things, that water shall be shared equally between the two countries. Canadian legislation and a Presidential Order designated, respectively, Ontario Hydro and the Power Authority of the State of New York as the agencies of each nation responsible for construction and operation of their respective shares of the project.

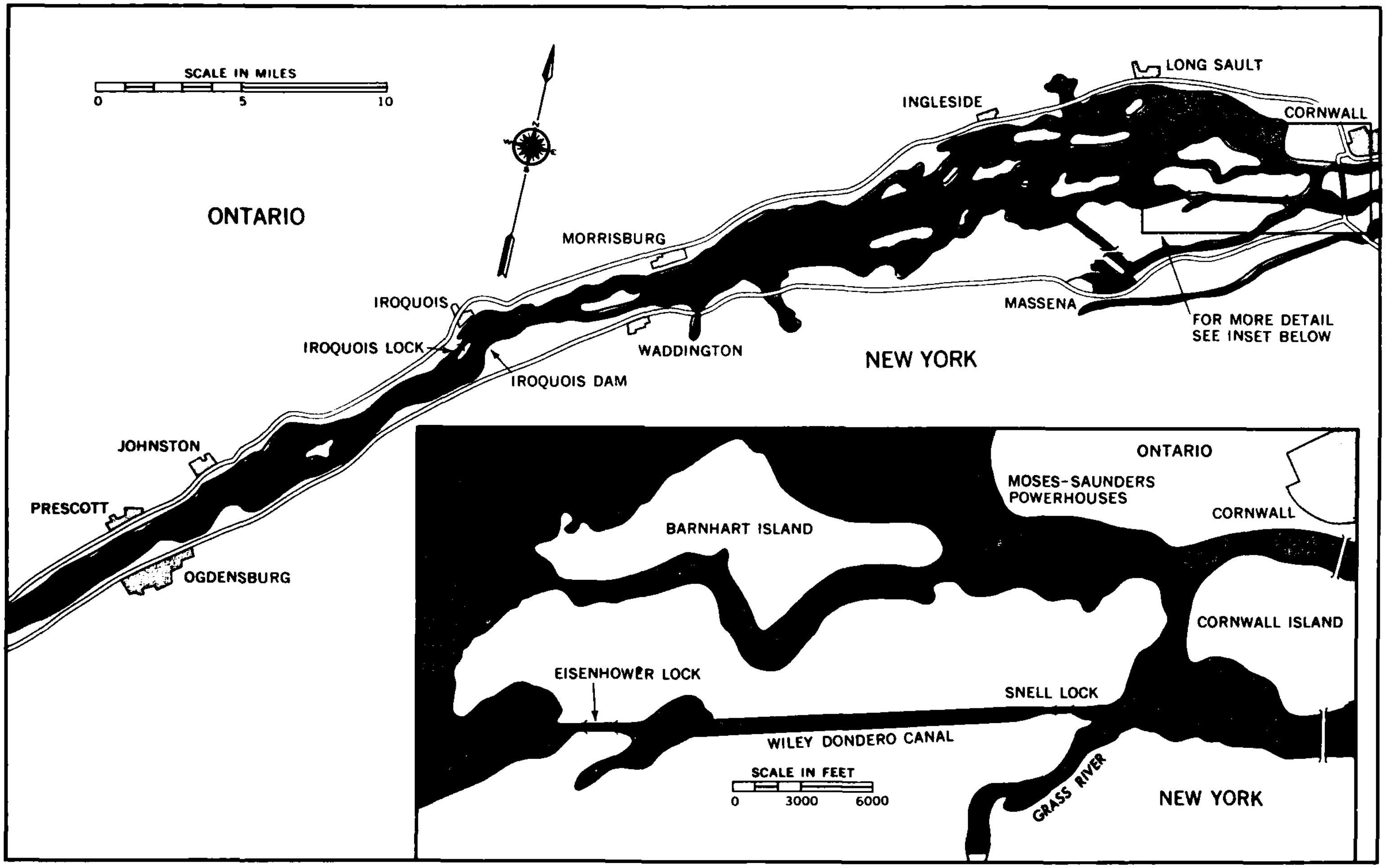
The St. Lawrence Power Project consists of a large power dam at Barnhart Island near Cornwall, Ontario, with the international boundary bisecting the dam (Figure 9). In one-half is Ontario Hydro's Robert H. Saunders St. Lawrence Generating Station and in the other the Power Authority's Robert Moses Power Dam. Each plant has 16 units with a rated head of 81 feet and an installed capacity of 912,000 kW or a combined total capacity of 1,824,000 kW. The power dam raises the preproject water level to form Lake St. Lawrence extending upstream some 40 miles. The Long Sault Dam, 3-1/2 miles upstream from the power dam, is a spillway. Upstream about 30 miles, the



PLAN OF SOULANGE SECTION OF ST. LAWRENCE RIVER

FIGURE 8

FIGURE 8



PLAN OF LAKE ONTARIO REGULATORY WORKS

FIGURE 9

FIGURE 9

Iroquois Control Dam is also capable of controlling the river profile to provide the depths necessary for deep-draft navigation in the downstream reaches. In the upstream reaches, extensive channel excavations were necessary to provide suitable velocities for navigation, and for stable ice cover in the winter.

Commercial production of power started in both plants in July 1958. The last of the 16 units was installed in July 1959 in the Moses Plant and December 1959 in the Saunders Plant.

2.6.2 Niagara River Plants

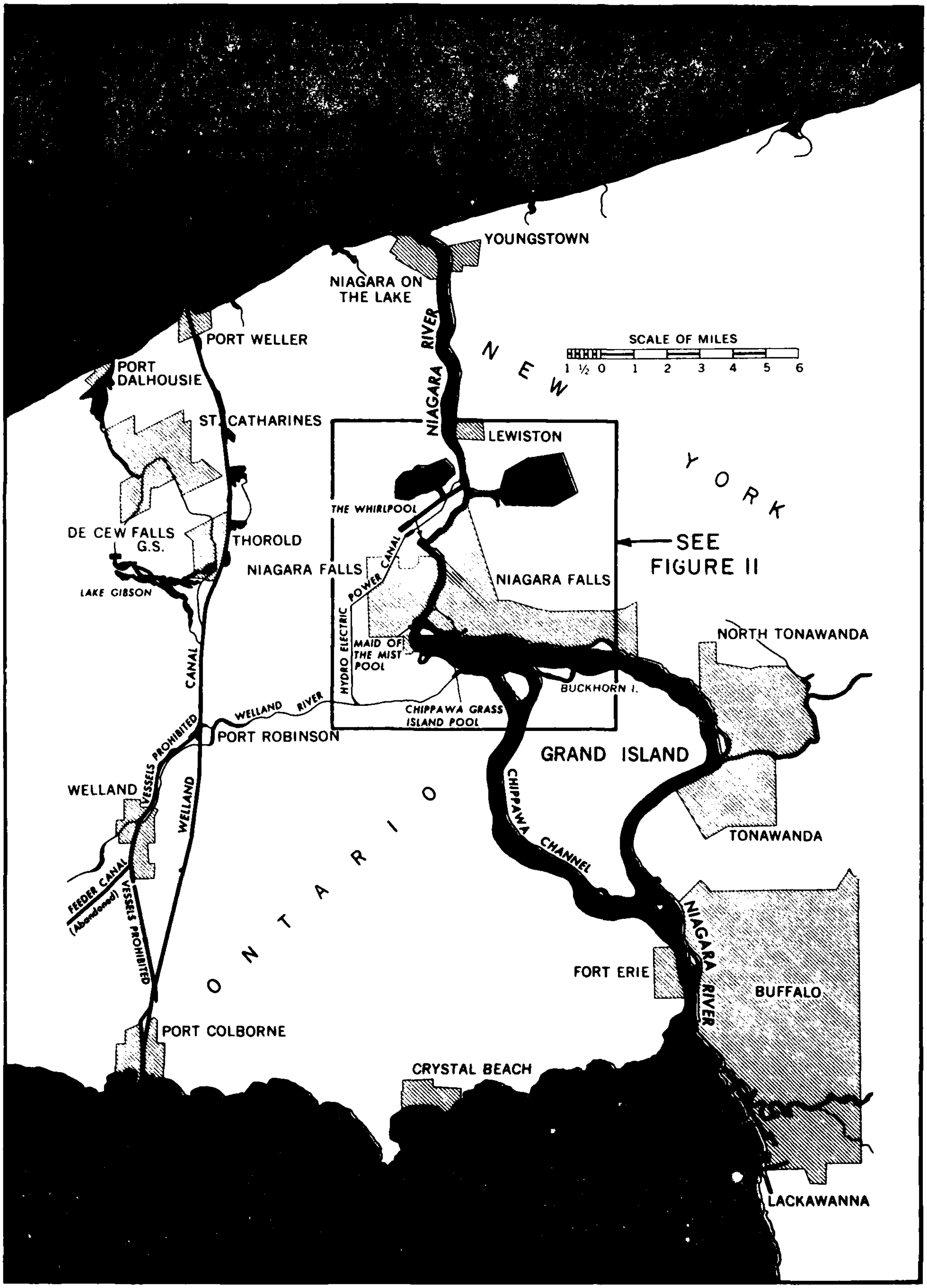
The outflow from Lake Erie which is utilized for power is diverted to the various hydroelectric plants by means of the Welland Canal and by intake structures at the Chippawa-Grass Island Pool about a mile upstream from Niagara Falls. Plants in Canada are served from both sources, whereas in the United States diversion is totally from the Niagara River at the Grass Island Pool. Figure 10 shows the general location of the Niagara River and Figure 11 shows the detailed locations of diversion structures and hydroelectric power plants at Niagara Falls.

The basis for determining the amount of water that can be diverted for power generation is contained in a Treaty between the Governments of Canada and the United States concerning "The Diversion of the Niagara River" dated 1950 and generally referred to as the 1950 Niagara Treaty.

Rather than stipulating the allowable diversions for power generation the Treaty stipulates the minimum flows over the Falls in prescribed periods, the remainder being available for power. Article III of the Treaty perpetuates an additional 5,000 cfs for Canada from the Ogoki-Long Lake Diversions which had previously been agreed to by an exchange of notes in 1940 between the two Governments.

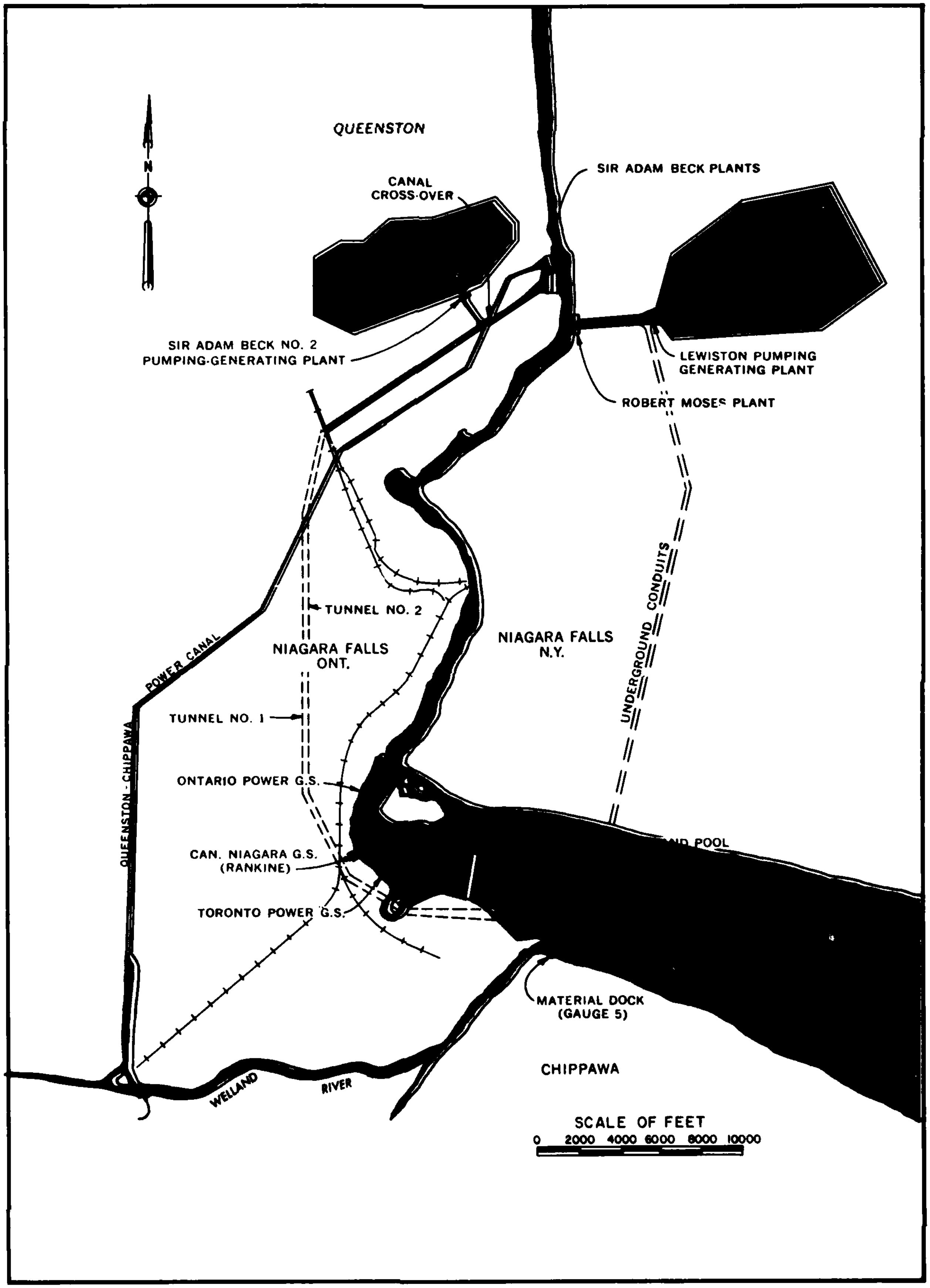
The Treaty requires that during the tourist season, from 8:00 am to 10:00 pm for the period April 1 to September 15, and from 8:00 am to 8:00 pm for the period September 16 to October 31, the flow over Niagara Falls must be not less than 100,000 cfs. At all other times, the flow must be not less than 50,000 cfs. All water in excess of these amounts reserved for scenic purposes may be diverted for power purposes. Remedial works were constructed by the power entities in the 1950's to facilitate power diversions and maintain Falls flows as permitted by the Treaty.

The remedial works consisted of excavation on either flank of the Horseshoe Falls and a control structure extending about 1/2-mile out from the Canadian shore to the international boundary at the downstream end of the Chippawa-Grass Island Pool. The structure regulates the water level in the Chippawa-Grass Island Pool. It also functions to alter the Falls flow promptly from 100,000 to 50,000 cfs and vice-versa during the tourist season.



PLAN OF NIAGARA RIVER - LAKE ERIE TO LAKE ONTARIO

FIGURE 10



NIAGARA RIVER—DETAIL LOCATION OF HYDROELECTRIC POWER PLANTS AND DIVERSION WORKS

FIGURE II

As stipulated by the International Niagara River Board of Control, the Chippawa-Grass Island Pool is maintained at its long-term average mean elevation of 561.0 feet IGLD (1955) with certain provisions for daily and monthly variation therefrom. The regulation of the pool does not have any measurable effect on the level of Lake Erie.

United States Plants: The Niagara Project was constructed by the Power Authority of the State of New York to utilize the full United States share of the waters of the Niagara River.

The Niagara Project consists of two water intakes and underground conduits, a forebay, a pump-storage generating plant (the Lewiston Pump-Generating Plant) with storage reservoir, a conventional hydro-electric generating plant (the Robert Moses Niagara Power Plant), and power transformation and transmission facilities.

Water is diverted from the Niagara River through two intakes above the Falls, flowing through covered conduits to the forebay of the pump-generating plant, and thence via an open canal to the Moses Plant, which is about 6 miles below the Falls. The pump-generating plant pumps the additional water available at night and weekends into a 69,000 acre-foot reservoir using off-peak power. Water released from the reservoir, when required to meet power demand, adds the reservoir generation to that provided by this same water at the Moses Plant. The open canal terminates at the edge of the gorge in a headworks structure from which penstocks deliver water to the turbines at the bottom of the gorge. The Moses plant has 13 units with an installed capacity of 1,950,000 kW at a rated head of 300 feet and has a maximum sustained diversion capability of about 102,000 cfs. The pump-generating plant has 12 units with an installed capacity of 240,000 kW at a rated net head of 85 feet.

Power was first generated in January 1961, and the final generator went into commercial operation in October 1962. The project was completed in November 1963.

Canadian Plants: There are seven hydroelectric plants on the Canadian side of the Niagara River, which take water either directly from the river or from Lake Erie via the Welland Canal, having a combined installed capacity of 2,158,190 kW. Table 12 lists the plants, number of units, rated head and installed capacity.

Table 12 - Hydroelectric Plants in Canada Using Outflow from Lake Erie

Plants	No. of Units	Rated Head (ft)	Installed Capacity (kW)
Sir Adam Beck No. 1	10	291-301	414,650
Sir Adam Beck No. 2	16	291-301	1,223,600
Pumping Generating Station	6	50-75	176,700
Ontario Power	12	205	101,460
Canadian Niagara Power Co. (Rankine)	11	126	94,680
DeCew Falls No. 1	6	266	31,900
DeCew Falls No. 2	2	283	115,200

Canadian Plants - Sir Adam Beck No. 1 : The construction of the Queenston-Chippawa Development, now known as Sir Adam Beck No. 1 Niagara Generating Station, started in 1921. The water is conveyed from a point 2-1/2 miles above the Falls some 14 miles via part of the Welland River and open canal to the powerhouse at the base of the Niagara Gorge, 6 miles downstream from the Falls. The canal was rehabilitated in 1964-65 and presently has a capacity of about 21,000 cfs.

Canadian Plants - Sir Adam Beck No. 2 and Pumping Generating Station: As the 1950 Niagara Treaty made more water available for power generation, Ontario Hydro constructed the Sir Adam Beck No. 2 Generating Station and a pump-generating plant. The intake for the new Sir Adam Beck Station is located in the Chippawa-Grass Island Pool above the Falls and the generating station is located alongside the Sir Adam Beck No. 1 plant. Water is conveyed to the plant through two tunnels, each 45 feet in diameter and 5-1/2 miles long and having a total flow capacity of about 43,000 cfs. Due to rock conditions about 2-1/2 miles from the plant the tunnels come to the surface and discharge into a large canal for the remaining distance, joining the original canal some 1/2 mile above the plant. The reservoir of the pumping-generating station has a capacity of 15,400 acre-feet. The water from this reservoir is used at both Beck Stations to meet daytime power demands.

Canadian Plants - DeCew Falls Generating Stations 1 and 2: The DeCew Falls Plants draw a daily average of 6,800 cfs from Lake Erie via the Welland Canal into a storage reservoir known as Lake Gibson. The maximum flow through the plants is limited to 7,800 cfs due to flooding constraints on Twelve Mile Creek which conveys the water from the plants to Lake Ontario.

DeCew Falls No. 1 Plant came into service between 1901 and 1911 and six of the original nine units are presently in operation. DeCew Falls No. 2 Plant was built as an extension to utilize the additional 5,000 cfs that was diverted into the Great Lakes by the Ogoki-Long Lake Diversions. The two units came into service in 1943 and 1947.

Canadian Plants - Cascade Plants: The cascade plants are the Ontario Power, Toronto Power and Canadian Niagara Power Plants which came into service between 1904 and 1924. They draw their water supply directly from the Niagara River between the present control structure and the Horseshoe Falls. The Toronto Power Plant was retired in 1974.

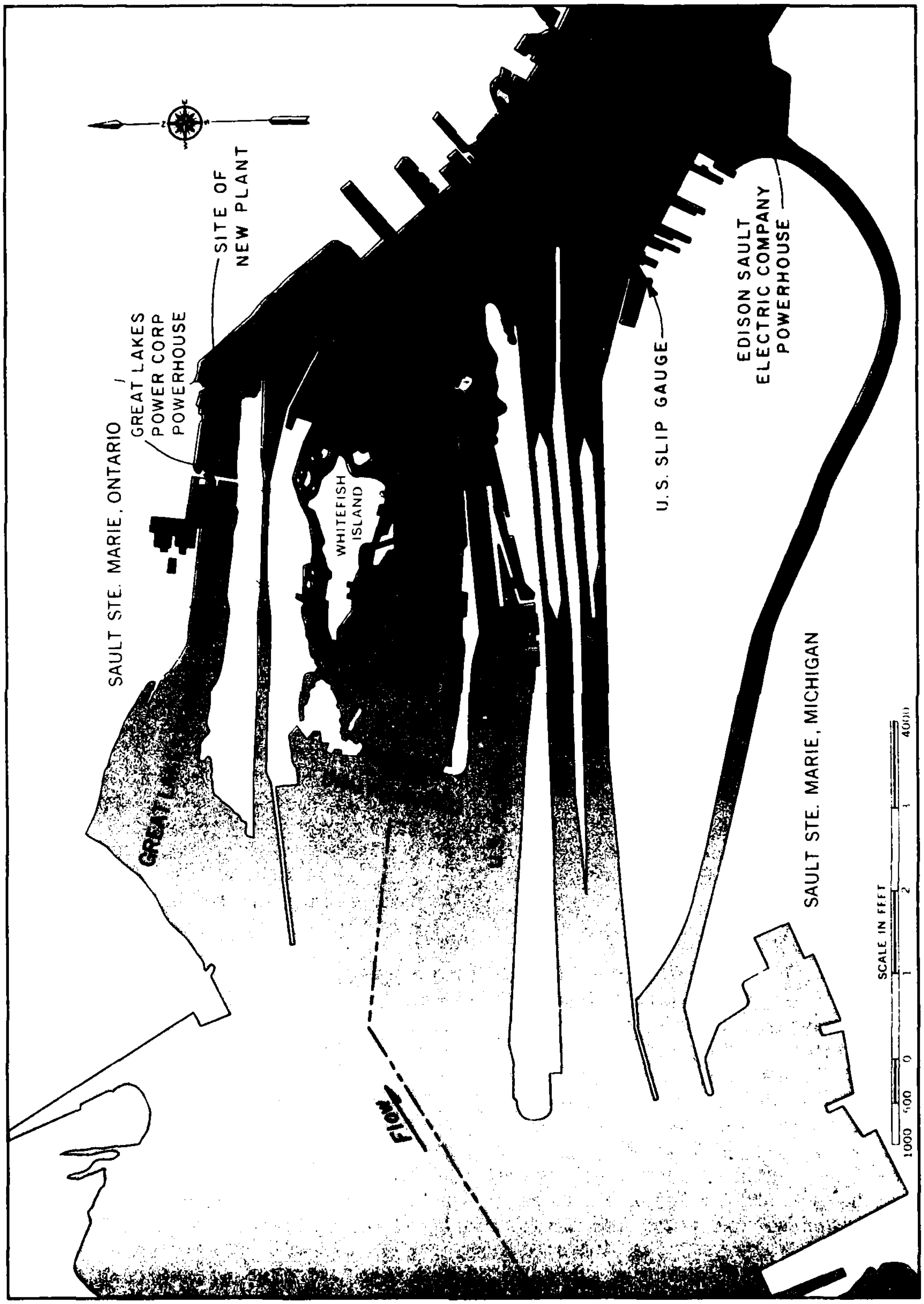
2.6.3 St. Marys River Plants

The St. Marys River forms the outlet of Lake Superior. From Whitefish Bay, at the east end of Lake Superior, the river flows in a general southeast direction to Lake Huron, a distance of approximately 70 miles. From its headwater on Whitefish Bay to its outlet on Lake Huron, the river falls about 22 feet, most of which (20 feet) occurs in the 1 mile long St. Marys Rapids at Sault Ste. Marie, Michigan and Ontario. At Sault Ste. Marie, various man-made facilities have been constructed since 1887. Since 1921 these facilities have enabled complete control of the outflow from Lake Superior and consist of navigation locks, hydroelectric power plants and compensating works. All water flowing out of Lake Superior through the St. Marys River must pass through one of these facilities. The general arrangement of plants is shown on Figure 12.

Canadian Plant: There is presently one hydroelectric plant on the Canadian side of the St. Marys River. This plant is owned by the Great Lakes Power Corporation and has 28 units, an installed capacity of 21,500 kw and can utilize about 18,000 cfs.

Great Lakes Power is redeveloping the St. Marys River site by replacing the old power plant with a new one immediately downstream. The new plant will have three units with a total installed capacity of 52,000 kW and utilize about 37,300 cfs at a rated net head of 18.7 feet. The intake canal will be deepened to accommodate the increased flow requirement. Construction of the new plant began in May 1979 and is scheduled to be in operation by the end of 1982. The power evaluation for this study was based on the estimated output from this new plant.

United States Plants: There are two hydroelectric power plants located on the United States side of the St. Marys River. The United States Government plant, which contains four units, is located at the foot of St. Marys Falls and has a total capacity of 16,000 kW. The plant also has one unit located at the head of the falls with a total capacity of 2,300 kW; all water used is taken from the same diversion canal and totals approximately 12,700 cfs at plant capacity. The Edison Sault Electric Company plant, located below the rapids, is served by a 2-1/2-mile long diversion canal which bypasses the rapids. This plant has a total capacity of 41,300 kW at a head of 20 feet with a water usage of approximately 30,500 cfs at rated plant capacity.



PLAN OF LAKE SUPERIOR REGULATORY WORKS

FIGURE 12

2.7 Great Lakes-St. Lawrence River Navigation System

2.7.1 Major Features

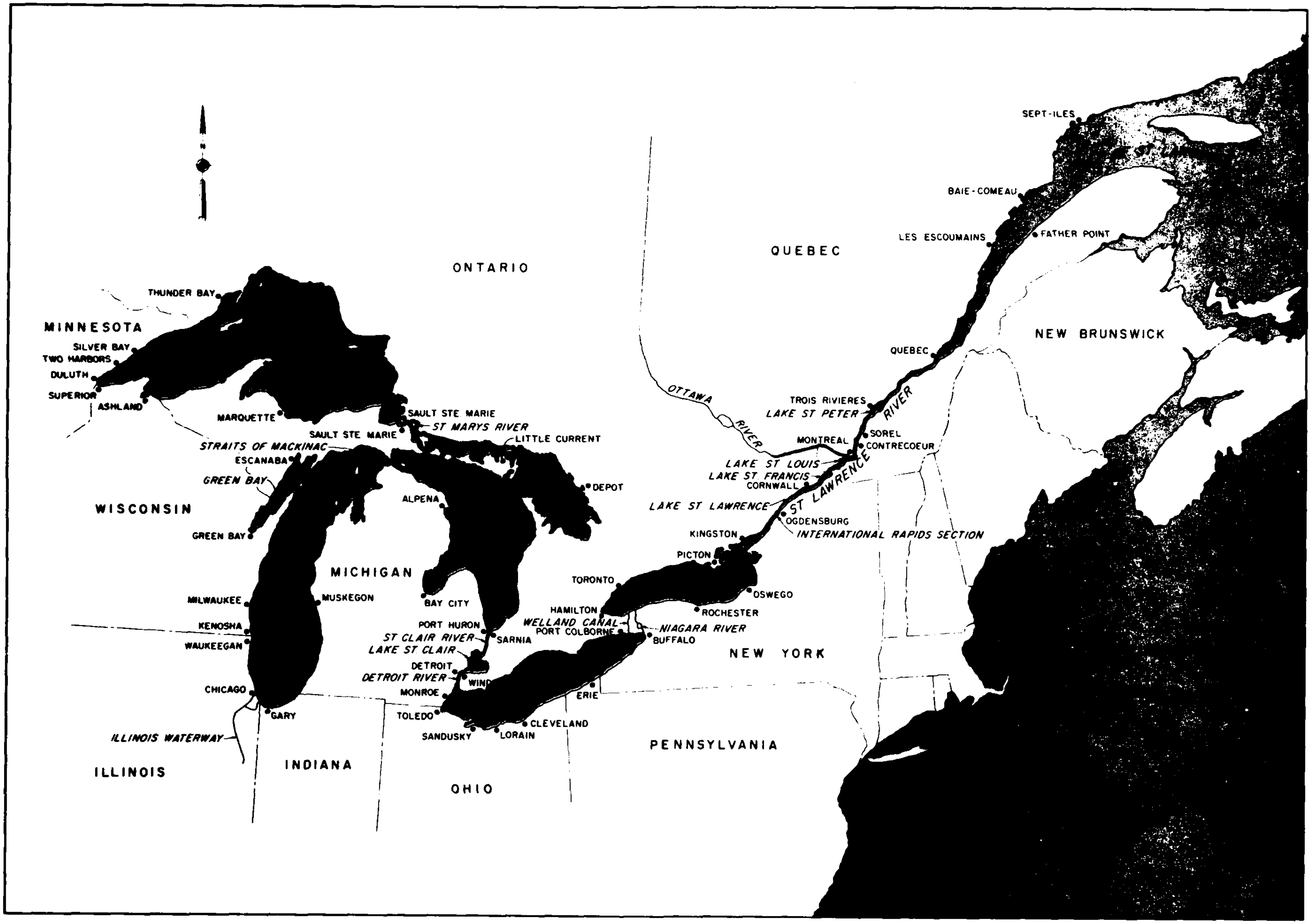
The Great Lakes and connecting channels, and the St. Lawrence River and the Gulf of St. Lawrence, provide for a continuous deepdraft waterway from the Atlantic Ocean 2,400 miles inland to the heart of the North American Continent. The navigation features and characteristics of this vast inland waterway are presented in Figure 13 and shown in Table 13.

The Great Lakes-St. Lawrence River connects with several other shallow draft inland navigable waterways to form an important transportation network reaching deep into the continent. At the south end of Lake Michigan, it connects with the Illinois Waterway Segment of the Mississippi River System. The Mississippi River and tributaries navigation system consists of 5,000 miles of navigable shallow draft channels and provides barge transportation from the Gulf of Mexico to ports in the central part of the United States. The New York State Barge Canal provides a shallow draft link between the Great Lakes and the east coast ports via the Hudson River. The shallow draft Richelieu-Champlain waterway system connects the Hudson River to the St. Lawrence River downstream of Montreal. In Canada, the Rideau, Trent, and Ottawa Canal systems link the hinterland with the Great Lakes and St. Lawrence River.

2.7.2 Economic Development and Area Resources

The Great Lakes-St. Lawrence River navigation system provides the means of transporting over 220 million tons of waterborne cargo annually. Part of the area served by the system, commonly referred to as the Mid-continent region, constitutes the industrial and agricultural heartland of North America. It encompasses 19 States and the three Canadian Provinces: Ontario, Manitoba, and Saskatchewan. Over 80 million people, some 30 percent of the combined populations of Canada and the U. S., live in this area. This system also serves the large Canadian mining operations in Quebec and Labrador and metropolitan areas on the St. Lawrence River in Quebec.

The Mid-continent of North America is a highly productive area. It produces about 34 percent of the combined gross national products of the United States and Canada, a third of their capital investments, and about 30 percent of their combined personal incomes. Its economy, industrial and agricultural, accounts for 37 percent of values added to manufacture in Canada and the United States, and over 42 percent of the two countries' total agricultural income. Heavy industry is predominant (steel, transport equipment, metals, and machinery). The agricultural sector is concentrated on grains, livestock, dairy, and poultry products, with much of this production being surplus to the area's requirements. At the same time, the region is a net importer of light and diversified industry products, fiber, fish, and forestry products. The Mid-continent region depends heavily upon transportation, initiating 42 percent of the total tonnage of rail freight in the United States, and 45 percent of the rail movement in Canada, and being the destination for over 41 percent of the rail shipments of the United States and 38 percent in Canada. Moreover, it is the strategically located



GREAT LAKES - ST. LAWRENCE NAVIGATION SYSTEM

FIGURE 13

FIGURE 13

Table 13 - Physical Dimensions of the Great Lakes - St. Lawrence River Navigation System

Reach	Lakes and Channels: Open Waters (Miles)	Lakes and Channels: Channels & Canals (Miles)	Lakes and Channels: Depth (Min) (Ft.)	Locks: Number	Locks: Year Completed	Locks: Size Length X Width (Ft.)	Locks: Depth over Sill (t)	Locks: Lift (Ft.)
Atlantic Ocean to Father Point, Que.	700	-		-	-	-	-	-
Father Point to Montreal	300		35	-	-	-	-	-
Montreal to Lake Ontario	189							226
Lachine Section		31	27	2 (Can.)	1958	800X80	30	
Soulanges Section		16	27	2 (Can.)	1958	800X80	30	
International Rapids Sec		44	27	1 (Can.)	1958	800X80	30	
Lake Ontario, Kingston to Welland Canal	160	-	-	-	-	-	-	-
Welland Canal	-	27	27	8	1932	800X80	30	326
Lake Erie, Welland Canal to Detroit River	236	-	27	-	-	-		-
Detroit River to Lake St. Clair and St. Clair River	-	77	27	-	-	-	-	-
Lake Huron, St. Clair River to St. Marys River	223	-	-	-	-	-	-	-
Lake Michigan, Chicago to the Straits of Mackinac	345	-	-	-	-	-	-	-
St. Marys River (includes Soo Locks)	70	2	27	2 (U.S.)	1919	1,350X80	23.1	22
				1 (U.S.)	1943	800X80	31.0	22
				1 (U.S.)	1968	1,200X110	35.0	22
				1 (Can.)	1895	900X59	16.8	22
Lake Superior, St. Marys River to Duluth	383	-	-	-	-	-	-	-

centre of both nations through which most of the other east-west interregional traffic and much of the north-south contiguous trades must flow. The United States Midcontinent portion generates over one-third of the nation's exports of manufactured products.

2.7.3 Factors Influencing Navigation

Water Levels and Flows: The water levels of the Great Lakes vary from year to year, and from month to month during each year. The higher levels for the year occur during the summer months. The lower levels occur during the winter months. The seasonal variation between the summer high and the winter low averages about 1 foot on the Upper Lakes, 1-1/2 feet on Lake Erie, and nearly 2 feet on Lake Ontario.

One inch of vessel draft on a freighter having a 25,000 ton carrying capacity represents 125 short tons of cargo. On a 1,000-foot, 65,000 ton capacity bulk carrier, 1 inch means a loss or gain of 220 tons or about 0.3 percent of carrying capacity. It is evident that raising or lowering of water levels affects the draft to which seaway ships may load and, hence, the volume and the unit cost of cargo movements. It is therefore desirable that a relatively stable water level, which is uniformly balanced relative to low water datum, be maintained on the Great Lakes, and that occurrences of extreme low lake levels be reduced.

Safe navigation also depends on adequate width and depth of connecting channels, and on reasonably uniform flow. Major variations in channel flows generally adversely affect navigation. Similarly, changes which would require the use of the existing lock and canal for regulation purposes, such as the Black Rock Canal, would affect navigation.

Weather: Severe weather conditions particularly in late fall and in early spring complicate ship, lock, and cargo handling operations and reduce available operating time. Many ship owners cease vessel operations prior to the actual closing of the navigation season to avoid severe storms.

Shoaling: Shoaling (deposition of sediments) is a serious and costly problem at nearly all harbors, and in most navigation channels. Maintenance of navigation depths is a continuing operation throughout the system.

2.8 Recreational Beaches

The area studied extends from the head of the St. Clair River to the New York State - Province of Quebec border. Approximately 80 miles, or 4 percent of shoreline in this study area, are publicly accessible recreation beaches (U.S.: 27 percent; Canada: 73 percent). Many of these beaches are of high quality and provide a wide range of recreational beach activities. Examples include: Rondeau, Long Point and Sandbanks in Canada and Hamlin (New York), Presque Isle (Pennsylvania), and Cedar Point (Ohio), in the United States.

A summary of beach physical characteristics is presented in Table 14. Proportionately, Lake St. Clair including St. Clair River beaches total 1.4

Table 14 - Beaches in the Study Area

Waterbody	Reach	Beaches Length (feet)	Beaches Area 1/ (sq. feet)
Lake St. Clair (includes St. Clair River)			
Canada	Chatham (LSt.C)	4,462	
United States	R001	0	0
	R002	2,575	298,800
			298,800
Total		7,037	
Lake Erie (includes Detroit River & Upper Niagara River)			
Canada	Chatham (LE)	55,406	
	Aylmer	13,471	
	Simcoe	31,409	
	Niagara (LE)	39,809	
Subtotal		140,095	
United States	R003	1,094	143,200
	3001	1,010	193,800
	3002	8,696	838,400
	3003	30,032	2,955,900
	3004	42,674	5,076,100
	R004	2,020	298,600
Subtotal		85,526	9,506,000
Total		225,621	
Lake Ontario (includes Lower Niagara River)			
Canada	Niagara River(LO)	15,533	
	Cambridge	15,800	
	Maple	46,468	
	Lindsey	19,762	
	Napanee (LO)	58,226	
Subtotal		155,789	
United States	R005	0	0
	2001	4,608	420,000
	2002	5,130	717,300
	2003	6,096	730,500
	2004	4,524	426,400
	2005	1,537	72,100
Subtotal		21,895	2,366,300
Total		177,684	
St. Lawrence River			
Canada	Napanee (SLR)	3,510	
	Brookville	4,494	
	Cornwall	8,771	
Subtotal		16,775	
United States	R006	1,074	62,200
	R007	0	0
	R008	2,405	332,200
Subtotal		3,479	394,400
Total		20,254	
Study Area			
Canada		317,121	
United States		113,475	12,565,500
Total		430,596	

1/ Areas for Canadian beaches were not determined

miles (U.S. 37 percent; Canada 63 percent), Lake Erie has a total of 43 miles of beach (U.S. 38 percent, Canada 62 percent), Lake Ontario 34 miles of beach (U.S. 12 percent, Canada 88 percent), and St. Lawrence River 3.8 miles of beach (U.S. 17 percent, Canada 83 percent).

Each public beach in the study area was measured and the areas totalled by reach and lake/river. Beach area calculations were based on the long-term average water level under the basis-of-comparison conditions.

2.9 Recreational Boating - U.S. Only

Since no marina and recreational boating data were available within the study area (head of the St. Clair River to the New York State - Province of Quebec border) an inventory was conducted. However, due to financial limitations, the inventory was limited to United States waters. The total United States study area contains 662 boating facilities (marinas). Over 90 percent are in private ownership, with municipal and State Governments owning the rest. A few boating facilities on public lands are operated by a private concessionaire under lease to the Government (local, State, or Federal). A total of over 52,000 wet berth/slips and 700 moorings are located throughout the survey area (see Table 15). Over 40,000 boats can be stored on the property of these boating facilities. Almost half (319) of the facilities have some type of launch ramp. Most of the facilities (466) have some type of hoist to accommodate boaters' needs. The occupancy for the wet berth/slips is about 88 percent. This means that almost 46,000 of the available slips are utilized during the boating season. A total of 81 percent of the moorings are occupied. About 54 percent of the marinas set aside slips for transient use.

Table 15 - United States Boating Facility Capacity

	Lake St. Clair (includes St. Clair River)	Lake Erie (includes Detroit & Upper Niagara Rivers)	Lake Ontario (includes Lower Niagara River)	St. Lawrence River	Total Study Area
Wet Berths/Slips	11,215	33,522	6,141	1,304	52,182
Moorings	0	225	517	0	742
Dry Storage	11,400	23,066	4,997	894	40,357
Launch Ramps	35	186	80	18	319
Launch Capacity (Boats/Hr.)	329	1,415	642	148	2,534
Ramp Parking Spaces	1,671	8,236	5,148	836	15,891
Hoist	133	241	72	20	466

The fleet mix was established by reach for both wet berths/slips and moorings. The fleet mix for wet berths/slips for the total study area is shown in Table 16. A total of nearly 55 percent of the boats are in the 16 to 26 foot class, with over 35 percent in the 26 to 39 foot class. About 44 percent of the boats are of either the outboard, inboard/outdrive, or inboard class. About 19 percent of the boats are either sailboat or auxiliary sailboats (with engine). About 35 percent are some type of boat with overnight cruising facilities. The remainder are either houseboats, pontoon boats, or some form of other craft.

Table 16 - Fleet-Mix, Wet Berths/Slips

	Less Than 16 Ft.	16 to 26 Ft.	26 to 40 Ft.	40 to 64 Ft.	64 and Over	Total
Outboard	2,821	3,607	31	21	0	6,480
In/Outboard	440	11,565	933	0	0	12,938
Inboard	73	3,051	661	0	0	3,785
Sailboat	94	493	524	42	0	1,153
Aux. Sailboat	115	4,666	3,911	157	0	8,849
Cruiser	21	5,064	11,775	1,038	21	17,919
House/Pontoon	0	94	619	147	0	860
Other	136	42	63	10	10	261
Total	3,700	28,582	18,517	1,415	31	52,245

The fleet mix of the moorings is shown in Table 17. The bulk of these (51 percent) are 26 feet or larger. Nearly all (92 percent) are either sailboats or auxiliary sailboats.

Table 17 - Fleet-Mix, Moorings

	Less Than 16 Ft.	16 to 26 Ft.	26 to 40 Ft.	40 to 64 Ft.	64 and Over	Total
Outboard	10	0	0	0	0	10
In/Outboard	0	10	0	0	0	10
Inboard	0	10	0	0	0	10
Sailboat	0	38	29	0	0	67
Aux. Sailboat	10	228	295	0	0	533
Cruiser	0	10	10	0	0	20
House/Pontoon	0	0	0	0	0	0
Other	0	0	0	0	0	0
Total	20	296	334	0	0	650

Future boating activity is projected to increase. This is due in part to the general population increase projected for the study area. Future boat types (fleet mix) may change. The current trend is towards sailboats which generally have more draft than similar sized power boats.

Section 3

SELECTION OF LEVEL AND FLOW REGIME FOR COMPARISON PURPOSES

3.1 General

In order to have a common basis on which to compare the effects of various Lake Erie regulation plans, a set of lake levels and outflows termed the basis-of-comparison was developed. These levels and outflows reflect a constant or fixed regime in the Great Lakes-St. Lawrence River System over the study period. The levels and outflows resulting under any Lake Erie regulation plan were compared with this basis-of-comparison, thus providing a consistent evaluation over the period of record.

The historic or recorded Great Lakes levels and outflows could not be used because they reflect changes which have occurred over the period of record. The principal changes were man-made and consist of changes in the amount of diversion into and out of the Great Lakes basin, alterations in the configuration of the connecting channels, and the erection of control structures at the outlets of Lakes Superior and Ontario. In addition to these man-made changes, the movement of the earth's crust in the Great Lakes basin, a natural phenomenon, has been progressively changing the tilt of the basin with a resultant gradual change in the relative elevations of individual lake outlets, inlets and intermediate points on each lake. Therefore, to identify and evaluate the effects solely attributable to limited regulation of Lake Erie, the present outlet regime and methods of regulation were assumed in effect throughout the study period.

The following paragraphs provide a short description of the recorded data employed and the derived data developed to establish the basis-of-comparison for this study.

3.2 Selected Study Period

Although observations of the water levels of the Great Lakes have been taken almost continuously since 1860, only a few discharge measurements of the outflows from the lakes were made prior to the turn of the century. In order to use the most uniformly consistent and reliable observations as possible for each of the lakes and their outlet rivers, and also to have a reasonably long record for developing and evaluating regulation plans, the period from January 1900 to December 1976 was selected. This 77-year period is known as the "study period" throughout this report. It contains basin-wide drought years, such as those of the mid-1930s and mid-1960s, as well as several high supply years, such as those in 1928-1929, 1951-1952, and the early 1970's. Hence, it was considered adequate for assessing the effects of the regulation plans.

3.3 Recorded Data

The recorded data, such as lake levels, outflows, and diversions, were taken from records on file in the United States at the National Oceanic and

Atmospheric Administration, Department of Commerce, and at the U. S. Army Corps of Engineer District, Detroit, Department of the Army; and in Canada at the Inland Waters Directorate, Environment Canada, and at the Marine Environmental Data Service, Department of Fisheries and Oceans. The data developed by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data and agreed to by user Federal agencies of both countries were employed where possible. Where coordinated data did not exist, the missing data were developed and coordinated.

3.4 Assumptions

To determine the required water supply data (Section 3.5.1) and develop the basis-of-comparison, the following assumptions were made:

a. That no adjustments would be made for changes in the hydraulic and hydrological characteristics (such as tributary stream regulation, increased urbanization, consumptive use, etc.) of the Great Lakes basin, but would be as they occurred over the study period, and as reflected in the recorded data.

b. That due to the large area of each of the Great Lakes in comparison to changes in the area as a result of changes in stages, a single storage conversion constant relating the volume of water represented by a given change in stage to cfs-months over the entire range of stage for each lake would be employed. The constants are as follows:

Lake Superior:	0.00296 foot per thousand cubic feet per second for 1 month (TCFS-mo.) or 337,800 cubic feet per second for 1 month for each foot (CFS-mo./ft.)
Lakes Michigan-Huron:	0.00208 ft./TCFS-mo. or 480,800 CFS-mo./ft.
Lake Erie:	0.00951 ft./TCFS-mo. or 105,200 CFS-mo./ft.
Lake Ontario:	0.0125 ft./TCFS-mo. or 80,000 CFS-mo./ft.

c. That all months have the same number of days (30.4 days).

3.5 Derived Data

Due to their larger surface area, the levels of Lake Superior and Lakes Michigan-Huron respond to changes in water supply much more slowly than do the levels of Lakes Erie and Ontario (Lake Ontario six times as fast as Lakes Michigan-Huron). For this reason, the basic data used in this study were developed and coordinated for monthly periods on Lakes Superior and Michigan-Huron, and quarter-monthly periods on Lakes Erie and Ontario. Lake St. Clair reflects conditions on Lakes Michigan-Huron and Erie, however monthly periods were employed for that lake. Data derived for formulating the basis-of-comparison, and for testing lake regulation plans, are described below.

3.5.1 Net Basin Supplies

Net Basin Supply (NBS), is a term used to describe the water which a lake receives from precipitation on both its surface and land drainage basin less the net effect of evaporation and condensation on the lake surface. Although presently available techniques do not permit the accurate determination of these factors separately, the net basin supplies can be computed quite accurately by employing recorded lake level, flow, and diversion information. The effects of groundwater are automatically included by this process. The relationship used is as follows:

$$NBS = S + O - I$$

where:

NBS = Net Basin Supply;
S = Change in storage from beginning to end-of-period;
O = Average outflow from the lake through the outflow river, and diversions out of the lake; and
I = Average inflow to the lake from the inflow river and diversions into the lake.

All terms in the above relationship are expressed in consistent units, usually cubic feet per second. By employing the above equation, it was possible to compute the net basin supplies for each lake for the period 1900 to 1976.

3.5.2 Winter and Weed Retardation

The flows in the outlet rivers of the lakes during the winter season are often retarded materially by ice formation and by ice jamming. These conditions are not predictable for any specific winter, either as to severity or the exact timing of occurrence. The natural retardation of flows under ice conditions causes the levels of unregulated lakes to be higher at the time of the spring breakup than the levels would be if there were no ice, and this increases the storage on the lake.

The water level of Lake Superior and the outflow through the St. Marys River are regulated by the International Lake Superior Board of Control under authority of the International Joint Commission. The physical control is achieved by a dam, power canals, and other structures at the head of the St. Marys Rapids at Sault Ste. Marie, Michigan/Ontario. Under present regulation conditions, the winter retardation effect on the discharges is virtually zero. Since Lake Superior was considered to be regulated in developing the basis-of-comparison and regulation plans for Lake Erie, it was not necessary to consider winter retardation in the St. Marys River.

Lakes ... gan-Huron generally do not freeze over completely during the winter, primarily due to the influence of wind and the heat stored in the lake. The ice which forms in exposed central parts of the lake is continually broken up and moved about by the action of the wind. Some of this ice finds its way into the St. Clair River. As a result of these heavy runs of ice, jams occur which materially reduce the normal flow and in turn affect

both the upstream and downstream levels. The supply of ice delivered to the St. Clair River and the consequent degree of jamming is highly variable (January through March average flow retardation 23,000 cfs) and is an important factor of the natural winter regime. Hence, any derived basis-of-comparison must give consideration to the month-by-month magnitude of this retardation. Winter retardation in the St. Clair River was computed for use in this study by subtracting the recorded St. Clair River flow from the corresponding discharge computed from the open water discharge relationship for the gauges at Harbor Beach, and St. Clair Shores, Michigan.

Lake St. Clair normally freezes over in early winter and shields the Detroit River from heavy ice runs. The Detroit River itself frequently freezes over in its lower reaches. However, due to the size of Lake St. Clair, even a small retardation (January through March average 4,000 cfs) influences its level regime. Therefore, for use in this study, winter retardation in the Detroit River was determined to be the difference between the flow computed from the open water discharge relationship for the gauges at St. Clair Shores, Michigan, and Cleveland, Ohio, and the recorded flow.

Similar to Lake Huron, the principal problem with ice in Lake Erie and the Niagara River results from breakup of lake ice fields and the wind pushing the ice into the river. Since the winter of 1964-65, an ice boom has been installed near the head of the Niagara River by the Power Entities. Its purposes are to assist in the formation of a stable ice cover and to reduce the frequency and duration of ice runs during storms. The presence of the ice boom has reduced ice runs in the Niagara River.

Studies have shown that the weed effect in the Niagara River is much the same from summer to summer, but the ice effect varies considerably from one winter to another. Since the Lake Erie outlet conditions of 1953 were adopted as a condition for developing the basis-of-comparison for Lake Erie (Section 3.6), average weed and winter retardation were assumed. The average maximum ice retardation occurs in February and is about 4,700 cfs, while the average maximum weed retardation occurs in July and is about 5,100 cfs.

Lake Ontario has been regulated since 1960. Since the basis-of-comparison assumes this condition for the entire study period, no winter retardations were required for the calculations of effects on the upper St. Lawrence River. Reduction in the winter flow at the outlet of Lake St. Louis was calculated directly as the difference between the discharges derived from its approximate open-water stage discharge curve and the recorded discharges.

3.6 Basis-of-Comparison

The recorded Great Lakes levels and outflows data reflect the effects of changes in the regime of the lakes and connecting channels which have occurred over the study period (1900-1976). The principal changes to the system were man-made and consist of changes in the amount of diversion into and out of the Great Lakes basin, alterations in the configuration of the connecting channels, and the construction of control works at the outlets of Lake Superior and Lake Ontario.

In order to permit the hydrologic comparison of various regulation plans on a constant basis over the period of study, a set of uniform conditions within the Great Lakes system was adopted and corresponding adjustments to the recorded levels and outflows were made. The levels and flows occurring under these uniform conditions were also employed as a basis for assessing the possible benefits/losses resulting under the various plans.

The conditions selected for developing the basis-of-comparison are as follows:

1. A constant diversion of 5,000 cfs into Lake Superior by way of Long Lake and Ogoki diversions. This diversion was the subject of an exchange of notes dated October 14 and 31, and November 7, 1940, between the Governments of the United States and Canada and was perpetuated by Article III of the 1950 Niagara River Treaty.

2. Lake Superior regulated in accordance with Regulation Plan 1977.

3. A constant diversion of 3,200 cfs out of Lake Michigan at Chicago. This is the maximum long-term allowable diversion at Chicago as specified by decree of the U. S. Supreme Court dated June 12, 1967. This decree was modified in November 1980 to provide for a change in computational procedure. The maximum allowable diversion remains at 3,200 cfs.

4. 1962 Outlet conditions for Lake Huron. This represents the current Lake Huron outlet condition which has existed since the completion of the 27-foot navigation channel dredging in 1962.

5. A constant diversion, by way of the Welland Canal, of 7,000 cfs out of Lake Erie and into Lake Ontario. This has been the approximate average diversion through the Welland Canal during the latter years of the study period.

6. 1953 outlet conditions for Lake Erie. In its 1953 report on the Preservation and Enhancement of Niagara Falls, the International Joint Commission considered it essential that the relationship existing at that time between the Niagara River flow and the Chippawa-Grass Island Pool level be maintained following the commencement of operation of the Chippawa-Grass Island Pool Control Structure and power diversions as permitted by the 1950 Niagara River Treaty. The 1953 outlet conditions also represent the current Lake Erie outlet conditions.

7. Lake Ontario regulated during the period 1900-1960 in accordance with Plan 1958-D. In addition, for the period from 1960, Lake Ontario regulated with Plan 1958-D with discretionary deviations that have occurred in actual practice due to the extremes in supply sequences in the 1960's and 1970's.

8. Recorded conditions for the Ottawa River and local inflow to the St. Lawrence River.

The monthly mean level and outflow for each lake under the basis-of-comparison were obtained by routing through the system the recorded net basin supply, assuming a regime defined by the foregoing conditions. As a result, the effects of changing conditions in channel configurations, past diversions, and past regulation of Lakes Superior and Ontario, have been removed from the data. No adjustments were made in the data for the progressive effects of crustal movement and regulation of tributaries, flow variations due to ice and weed retardation and increasing rates of consumptive use.

The basis-of-comparison, therefore, is the water levels and outflows that the Great Lakes-St. Lawrence System would have experienced, for the period 1900-1976, had the foregoing conditions been in effect consistently throughout the 77 years. The water levels and outflows resulting from Lake Erie regulation plans would then be compared with the basis-of-comparison The differences between these two are the effects of limited regulation of Lake Erie.

In order to meet the requirements for combined regulation of Lakes Erie and Ontario, channel excavations would be required in both the International and Canadian Reaches of the St. Lawrence River. In Category 3 study, the amounts of channel enlargement, as well as modifications to Plan 1958-D, were determined for combined Lakes Erie and Ontario regulation. In order to evaluate the impacts due solely to limited regulation of Lake Erie, an adjusted basis-of-comparison was developed, and also used as basis for comparing the performance of the Category 3 regulation plans. The adjusted basis-of-comparison was developed in a similar manner as that for the basis-of-comparison and is described in Section 4.6.

Section 4
DEVELOPMENT OF REGULATION PLANS

4.1 General

Regulation implies a capability, through adjustable works constructed by man, for discretionary control of lake outflow. Full regulation requires works which can vary the outflow from zero to the maximum hydraulic capacity of the outlet. In the case of Lake Erie this would require full control of the flow through the Niagara River and Welland Canal. Limited regulation requires works which can modify, but cannot control, the total outflow from the lake. In this study limited regulation of Lake Erie implies the use of regulatory works to increase its outflows during periods of high supplies. At other times when supplies are low, the outflows could not be reduced below that under natural conditions.

To address the issues raised in the Government's Reference pertaining to this study, the Board conducted the study in three categories taking into account the combined regulation of Lakes Erie and Ontario. Categories 1 and 2 consider Lake Erie regulation constrained by the Commission's present Orders of Approval and channel limitations of the St. Lawrence River. However, they differed in that Category 1 considers that Lake Ontario was regulated in accordance with Plan 1958-D with discretionary deviations; whereas, under Category 2, Plan 1958-D would be modified to accommodate limited regulation and to satisfy the Commission's criteria for Lake Ontario to the same degree as occurred under the historic test and under operation since 1960 as represented by the basis-of-comparison. Category 3 considered channel modification and/or remedial measures in the St. Lawrence River to accommodate limited regulation of Lake Erie and to satisfy the Commission's Lake Ontario Orders of Approval, as written, over the entire test period (1900-1976).

A three-phase procedure was employed in the development of the regulation plans presented. Phase (1) consists of the development of an index which would be employed as a trigger to increase the outflow from Lake Erie; Phase (2) consists of the development of a series of regulation plans for Lake Erie that would increase its outflows by as much as 12.5 percent of the average; and Phase (3) consists of evaluating the impacts on Lake Ontario of the increased inflows from Lake Erie and of making the necessary revisions to Regulation Plan 1958-D to satisfy the objectives under Categories 2 and 3.

Phase (2) was further divided into three general groups; plans which confined activities (structures and dredging) to the Niagara River; plans which used the Black Rock Canal with a channel cut through Squaw Island for additional capacity; and lastly, plans which used the Black Rock Lock to pass increased flows.

4.2 Regulation Objective and Criteria

The primary objective of this study was to determine the feasibility of lowering the levels of Lake Erie by increasing its outflow during periods of

high water supply. The plans presented use channel improvements and control structures in either the Niagara River or the Black Rock Canal. In the case where the Niagara River is employed to obtain the additional capacity, full utilization of increased capacity of the regulatory works is possible at all times. However, in the case where the Black Rock Canal is used, it would be necessary to operate the structure intermittently resulting in the full capacity of the works only being employed part of the time on an annual basis. Intermittent operation of the control structure would be necessary to minimize the impacts on canal navigation and lock maintenance, and to provide for recreational use of the canal.

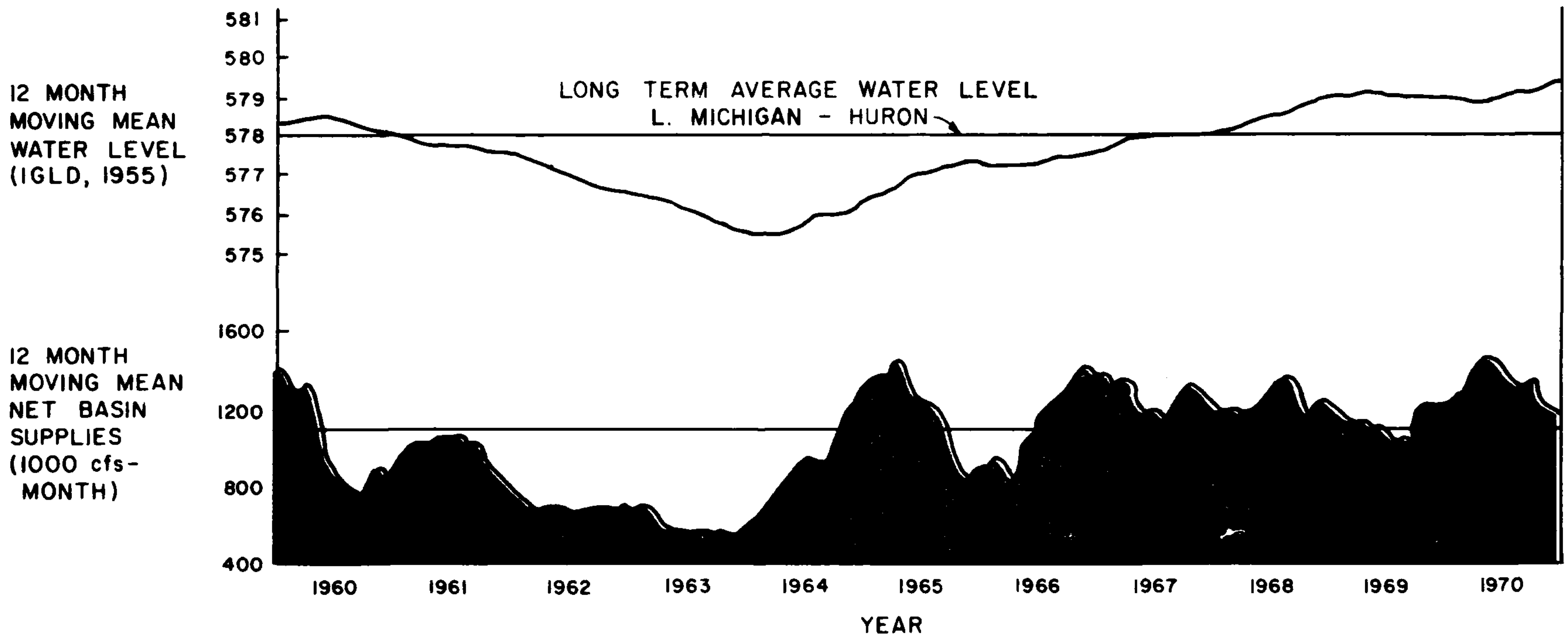
Since the objective of this study was to determine the economic and environmental feasibility and impacts of limited regulation of Lake Erie, no specific criteria for the actual regulation of that lake were established. The broad objective was to provide the maximum reduction in the frequency of occurrence of above average Lake Erie levels, while maintaining as nearly as possible the long-term mean and minimum levels. In evaluation of the impact on Lake Ontario, the Commission's criteria as given in the Orders of Approval of October 1952 and the 1956 Supplementary Order were used in comparing the performance of various regulation plans.

4.3 Index Development

The total water supply to Lake Erie has two components: (1) that which is supplied from the upper lakes; and (2) that which is contributed from its own basin. Of the two, the upper lakes contribution is more important. On the average, 80 percent of the water supply to Lake Erie comes from Lakes Superior and Michigan-Huron, with only about 20 percent being contributed by its own basin. Therefore, the levels of these upper lakes and/or the water supply to these lakes, in the long-term, provide an index as to future water supply conditions to Lake Erie.

Shown on Figure 14 are two possible indices for anticipating higher or lower water level conditions on Lake Erie. The upper curve is a plot of the 12-month moving mean of water levels on Lake Michigan-Huron, while the lower curve is a similar plot of net basin supplies to that lake. The diagram shows that the water supply index tends to move from below average to above, and vice-versa, sometime prior to the lake level indicator making similar excursions above or below the mean. Hence, employing water supply as an indicator would permit an earlier release of additional Lake Erie outflow in a rising lake level situation than the lake level index, and an earlier cessation of additional outflow in a falling lake level situation; thereby, maximizing the impact on the maximum lake level condition while minimizing the impact on the mean and minimum lake level values. The outflow from Lake Superior is regulated and, as such affects the levels of both Lakes Superior and Michigan-Huron. Hence the levels of these lakes may not be a true indicator of water which can be expected on Lake Erie for forecasting purposes.

Based upon the above rationale, the sum of the water supplies to Lakes Superior and Michigan-Huron were selected as an index of future water supplies to Lake Erie. In this study, to provide a smooth transition during



LAKE LEVEL VS WATER SUPPLY
(DEVELOPMENT OF TRIGGER)

FIGURE 14

FIGURE 14

changing supply conditions, a 12-month moving mean water supply to these lakes was employed as the index, or trigger, when additional flow should be released from Lake Erie.

4.4 Lake Erie Regulation Plans

As noted previously, the regulation studies were conducted under three separate categories. Category 1 develops the necessary plans for Lake Erie, and Categories 2 and 3 deal additionally with the necessary modifications to Lake Ontario Regulation Plan 1958-D and the necessary changes to the St. Lawrence River to handle an increased outflow from Lake Ontario. As noted in Section 4.1, plans for Lake Erie regulation under each category were subdivided into three groups: those which require a regulatory structure in the Niagara River; plans which use a diversion channel cut through Squaw Island; and lastly, plans which use the Black Rock Lock to discharge the additional quantities of water from Lake Erie. All of these plans are considered limited regulation schemes since none of the plans provide for full control of the outflow. The following paragraphs describe Lake Erie regulation plans for each of these groups. It should be noted that under Category 1, there was no change to Plan 1958-D to accommodate this increased inflow in order to satisfy the Commission's criteria for regulation of Lake Ontario.

4.4.1 Niagara River Plans

Niagara River (N) regulation plans require increased channel capacity by dredging and a control structure which extends partially across the Niagara River. The structure would be operated to increase the outflow from Lake Erie whenever the water supply to the upper Great Lakes was at or above normal. Whenever the water supply to the upper lakes dropped below normal, the total Lake Erie outflow would revert to that which would have occurred without structural modification. To provide for a range of impacts, costs, and benefits, a series of "N" plans was tested which increased the outflow from Lake Erie from 5,000 cfs up to 30,000 cfs in increments of 5,000 cfs. The resulting outflows from Lake Erie, under Category 1, for each of these plans, were routed through Lake Ontario in accordance with Regulation Plan 1958-D. The results of these tests are shown on Table 18.

4.4.2 Black Rock Canal - Squaw Island Plans

Black Rock Canal - Squaw Island (S) regulation plans utilize the existing Black Rock Canal to pass additional water out of Lake Erie. The water would be returned to the Niagara River downstream from the river's natural hydraulic control reach by a diversion channel which would be constructed across Squaw Island. A control structure in the diversion channel would be used to regulate the outflow from the Canal. The structure would be operated under these plans so as to increase the outflow from Lake Erie whenever the water supply to the upper Great Lakes is at or above normal. Whenever the supply drops below normal, the discharge through the structure would be reduced to zero.

Table 18 - Niagara River Plans, Categories 1 and 2
(Lake Levels in Feet, IGLD, 1955)

	Basis of Comparison	Plan 5N	Plan 10N	Plan 15N	Plan 20N	Plan 25N	Plan 30N
Lake Superior							
Mean	600.44	600.42	600.41	600.39	600.38	600.37	600.35
Max	601.93	601.93	601.93	601.93	601.93	601.93	601.92
Min	598.69	598.65	598.65	598.62	598.61	598.62	598.59
Range	3.24	3.28	3.28	3.31	3.32	3.31	3.33
Lake Michigan-Huron							
Mean	578.27	578.22	578.18	578.14	578.09	578.05	578.01
Max	581.15	581.07	580.99	580.92	580.84	580.75	589.68
Min	575.47	575.44	575.42	575.40	575.38	575.36	575.34
Range	5.68	5.63	5.57	5.52	5.46	5.39	5.34
Lake Erie							
Mean	570.76	570.64	570.52	570.40	570.29	570.17	570.05
Max	573.60	573.39	573.18	572.97	572.76	572.53	572.32
Min	568.09	568.04	567.99	567.94	567.89	567.84	567.79
Range	5.51	5.35	5.19	5.03	4.87	4.69	4.53
Lake Ontario (Category I-With Deviation)							
Mean	244.61	244.61	244.62	244.62	244.62	244.63	244.63
Max	247.37	247.38	247.40	247.43	247.48	247.50	247.54
Min	241.81	241.69	241.59	241.48	241.42	241.38	241.35
Range	5.56	5.69	5.81	5.95	6.06	6.12	6.19
Lake Ontario (Category 2)							
Mean	244.61	244.66	244.69	244.69	244.71	244.71	244.72
Max	247.37	247.37	247.39	247.42	247.43	247.45	247.46
Min	241.81	242.01	242.26	242.17	242.30	242.21	242.25
Range	5.56	5.36	5.13	5.25	5.13	5.24	5.21

The volume of water which can pass through the control structure is limited by the dimensions of the existing canal. Other factors include: the backwater effect of the Niagara River, and the maintenance of, and use of, the canal for commercial navigation and recreational boating. Giving consideration to these two above factors reduces the potential annual volume of water passing through the canal by about 38 percent. To provide for a range of impacts, costs, and benefits, a series of "S" plans was tested to cover the full range of possible increases in outflow from Lake Erie. The effective average annual increases in outflow for these plans range from 4,000 to 12,000 cfs. The resulting outflow, under Category 1, for each of these plans, were routed through Lake Ontario in accordance with Regulation Plan 1958-D. The results of these tests are shown on Table 19.

4.4.3 Black Rock Lock Plans

Black Rock Lock (L) regulation plans utilize the existing Black Rock Canal and require a modification to the existing lock so that its mitre gates can be opened and closed to allow water to flow through the lock chamber. The structure would be operated in a similar manner to that of the "S" plans.

In the use of the Black Rock Canal and Lock, the volume of water which can be passed through the area is affected by the same constraints that control outflows under the "S" plans. Giving consideration to maintenance and navigation would reduce the volume of water through the lock by about 46 percent. To provide for a range of impacts, costs, and benefits, two of the "L" plans were tested to cover the range of outflow from Lake Erie: a plan with an effective average annual release of 8,700 cfs, and a plan with an effective release of 3,700 cfs. The resulting outflows under Category 1 for each of these plans, were routed through Lake Ontario in accordance with Regulation Plan 1958-D. The results of these tests are shown on Table 20.

4.5 Category 2 - Modified Lake Ontario Plan 1958-D

As noted in paragraph 4.1, plans under Category 2 consisted of modifications to the operational rules of Lake Ontario Plan 1958-D to accommodate regulation of Lake Erie and to satisfy the Commision's criteria for the regulation of Lake Ontario to the same degree as occurred under the development of that plan and under actual operation since 1960 (as shown by the basis-of-comparison with discretionary actions; Condition #7 of Section 3.6). Since the purpose of the plans being presented herein was to establish feasibility, one plan under each of the "N", "S", and "L" plans was selected for consideration under Category 2 to cover the total range of flow increases. These three plans were selected based on the least cost of Niagara regulatory works, within each group of plans, to accomplish the same amount of lowering in Lake Erie levels. The plans are those designated as 25 N (which increases the outflow from Lake Erie by 25,000 cfs), 15 S (which increases the outflow from Lake Erie by 15,400 cfs, with an effective annual average release of 9,600 cfs), and 6 L (which increases the outflow from Lake Erie by 6,800 cfs, with an effective annual average release of 3,700 cfs).

Table 19 - Black Rock Canal - Squaw Island Plans, Categories 1 and 2 (Lake Levels in Feet, IGLD, 1955)

	Basis of Comparison	Plan 15S	Plan 19S
Lake Superior			
Mean	600.44	600.41	600.40
Max	601.93	601.93	601.93
Min	598.69	598.65	598.61
Range	3.24	3.28	3.30
Lake Michigan-Huron			
Mean	578.27	578.18	578.16
Max	581.15	580.99	580.96
Min	575.47	575.42	575.41
Range	5.68	5.57	5.55
Lake Erie			
Mean	570.76	570.53	570.47
Max	573.60	573.18	573.07
Min	568.09	568.02	568.00
Range	5.51	5.16	5.07
Lake Ontario (Category 1-With Deviation)			
Mean	244.61	244.65	244.65
Max	247.37	247.56	247.58
Min	241.81	241.59	241.61
Range	5.56	5.97	5.97
Lake Ontario (Category 2)			
Mean	244.61	244.69	244.72
Max	247.37	247.42	247.43
Min	241.81	242.12	242.15
Range	5.56	5.30	5.28

Table 20 - Black Rock Lock Plans, Categories 1 and 2
(Lake Levels in Feet, IGLD, 1955)

	Basis of Comparison	Plan 6L	Plan 16L
Lake Superior			
Mean	600.44	600.43	600.42
Max	601.93	601.93	601.93
Min	598.69	598.68	598.66
Range	3.24	3.25	3.27
Lake Michigan-Huron			
Mean	578.27	578.24	578.21
Max	581.15	581.09	581.07
Min	575.47	575.45	575.42
Range	5.68	5.64	5.65
Lake Erie			
Mean	570.76	570.67	570.61
Max	573.60	573.45	573.40
Min	568.09	568.07	568.02
Range	5.51	5.38	5.38
Lake Ontario (Category 1-With Deviation)			
Mean	244.61	244.64	244.61
Max	247.37	247.39	247.38
Min	241.81	241.74	241.69
Range	5.56	5.65	5.69
Lake Ontario (Category 2)			
Mean	244.61	244.66	244.69
Max	247.37	247.34	247.39
Min	241.81	242.04	242.26
Range	5.56	5.30	5.13

Regulation of Lake Ontario under Plan 1958-D consists of the selection of a quarter-monthly outflow from a basic rule curve and a comparison of that outflow with a series of outflow limitations. If the selected outflow is greater than the minimum limitations or less than the maximum limitations, the selected outflow is the outflow released from the lake. If, however, it falls outside the limitation, the limitation will govern the flow to be released. Under the Category 2 portion of this study, it is these limitations ("I", "P", "M", "J", and "L") which have been modified to accomplish the objectives of this study. Modifications to these limitations are discussed in the following paragraphs.

4.5.1 "I" Limitation

The "I" limitation under Plan 1958-D relates to the maximum permissible release of water from Lake St. Louis during the last half of December. This limitation was incorporated into Plan 1958-D to provide for ice formation under a proposed plan for the Lachine Rapids' power development. This development has not occurred. As a result, the International St. Lawrence River Board of Control has, on numerous occasions, waived this limitation under actual operation without adverse impact. Under Plans 25 N, 15 S, and 6 L, this restriction on the last half of December flow has been eliminated.

4.5.2 "P" Maximum Flow Limitation

This limitation restricts the regulated Lake Ontario outflow to an amount that would occur if preproject channel conditions still existed. This limitation was incorporated into Plan 1958-D so as not to aggravate flooding conditions in the Lake St. Louis-Montreal Harbour areas during the ice break-up period and during the annual flood discharge of the Ottawa River. The "P" limitation is applicable from February to mid-April, and from mid-April to the end of July for those periods when the outflow from Lake St. Louis, including the Ottawa River portion, exceeds 345,000 cfs. In practice during periods when water supplies to Lake Ontario exceeded those of the past, the "P" maximum flow limitation was applied at the discretion of the International St. Lawrence River Board of Control at about 380,000 cfs. Hence, a value of 380,000 cfs was adopted for use in Plans 25 N, 15 S, and 6 L under Category 2.

4.5.3 "M" Minimum Flow Limitation

IJC Criterion (e) for the regulation of Lake Ontario, states:

> "Consistent with other requirements, the minimum regulated monthly outflows from Lake Ontario shall be such as to secure the maximum dependable flow for power,"

Criterion (j) states:

> "The regulated level of Lake Ontario on 1 April shall not be lower than elevation 242.77. The regulated monthly mean level of the lake from 1 April to 30 November shall be maintained at or above elevation 242.77."

To satisfy these criteria, under Category 2 of this study, required some adjustment to Plan 1958-D minimum flow. The minimum flow employed in Plans 25 N, 15 S, and 6 L are shown in Table 21.

Table 21 - Minimum Permissible Lake Ontario Outflows for Plan 1958-D Under Category 2 (TCFS)

	Plan 1958-D	Plan 25N	Plan 15S	Plan 6L
Jan	210	202	204	205
Feb	207	200	200	202
Mar	204	195	196	195
Apr	188	188	188	188
May	188	188	188	188
Jun	190	190	190	193
Jul	193	190	190	200
Aug	193	195	195	201
Sep	193	202	202	202
Oct	193	202	204	205
Nov	198	202	204	205
Dec	210	202	204	205

4.5.4 "J" Outflow Variation

To restrict the variation in outflow from one quarter-month to the next, when no other flow limitation is applied, Plan 1958-D limits the change between regulation periods to 20,000 cfs. Under Category 2 plans, the limit has been raised to 45,000 cfs. The need for the greater flexibility is due to the sometimes sudden change in water supply, caused by the regulation technique being employed on Lake Erie.

4.5.5 "L" Outflow Limitation

To provide required depths and velocities for navigation and maintain a stable ice cover for power in the winter months, channel excavations were made in the St. Lawrence River during the construction of the St. Lawrence Seaway and Power Project. To keep the regulated Lake Ontario outflows and resulting levels and velocities in the river consistent with navigation and power requirements, restrictions have been placed on flow releases during various periods of the year. These restrictions are shown on Figure 15 and are applied under procedural application of Plan 1958-D. However, under actual operation conducted under Plan 1958-D (since 1960), some of these restrictions were related to a point when the stipulated maximum channel velocity of 4 feet/second was exceeded, but the minimum navigation depth was not. Employing these operational flows as a guide, modifications were made to the procedural values shown on Figure 16 to accommodate the increased inflow caused by regulation of Lake Erie under Plans 25N, 15S, and 6L. Under Category 2, there is no consideration for excavation in the International Rapids area to satisfy the navigation and power requirements.

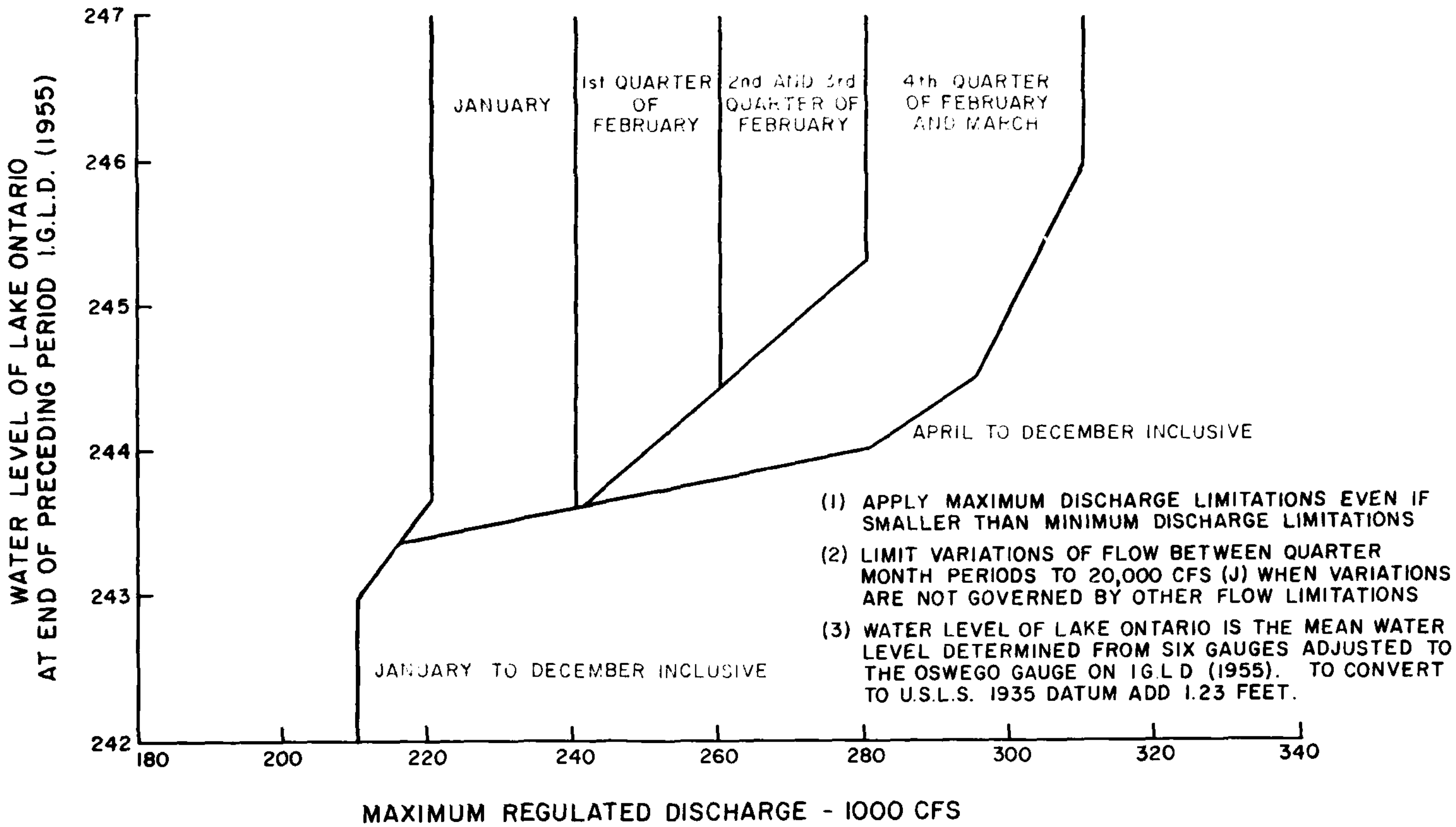
4.6 Category 3 - Modified Lake Ontario Plan 1958-D

4.6.1 Adjusted Basis-of-Comparison

Under Category 3, Sections 1.3 and 4.1 state that Regulation Plan 1958-D for the regulation of Lake Ontario will be modified to accommodate the combined regulation of Lakes Erie and Ontario. These modifications to Plan 1958-D will be made such that the resulting water levels and outflows of Lake Ontario when tested using the historical sequence of supplies will satisfy the criteria as written in the Commission's "Orders and Supplementary Orders of Approval" over the study period 1900-1976. As noted, Plan 1958-D was designed to cope with the recorded water supplies through 1954. It did not satisfy the stipulated criteria during the extreme supplies of the mid 1960's or early 1970's.

To provide an estimate of the channel enlargements that would be necessary in the St. Lawrence River to accommodate these extreme supplies, as well as any incremental channel enlargements necessary for the combined Lake Erie and Ontario regulation plans, two steps were required. First, it was necessary to adjust the Lake Ontario portion of the basis-of-comparison so that satisfaction of the Lake Ontario criteria were attained over the study period. This involved enlarging certain reaches in the St. Lawrence River and modifying Plan 1958-D. Levels and outflows over the period of record resulting from these modifications were called the adjusted basis-of-comparison. Comparing the levels and outflows from any Lake Erie plan under Category 3 with the levels and outflows from this adjusted basis-of-comparison measures the impact on Lake Ontario and the St. Lawrence River solely attributable to limited regulation of Lake Erie.

The following sections describe the modifications made to Plan 1958-D for the development of the adjusted basis-of-comparison and for Lake Erie Regulation Plans 6L, 15S, and 25N.

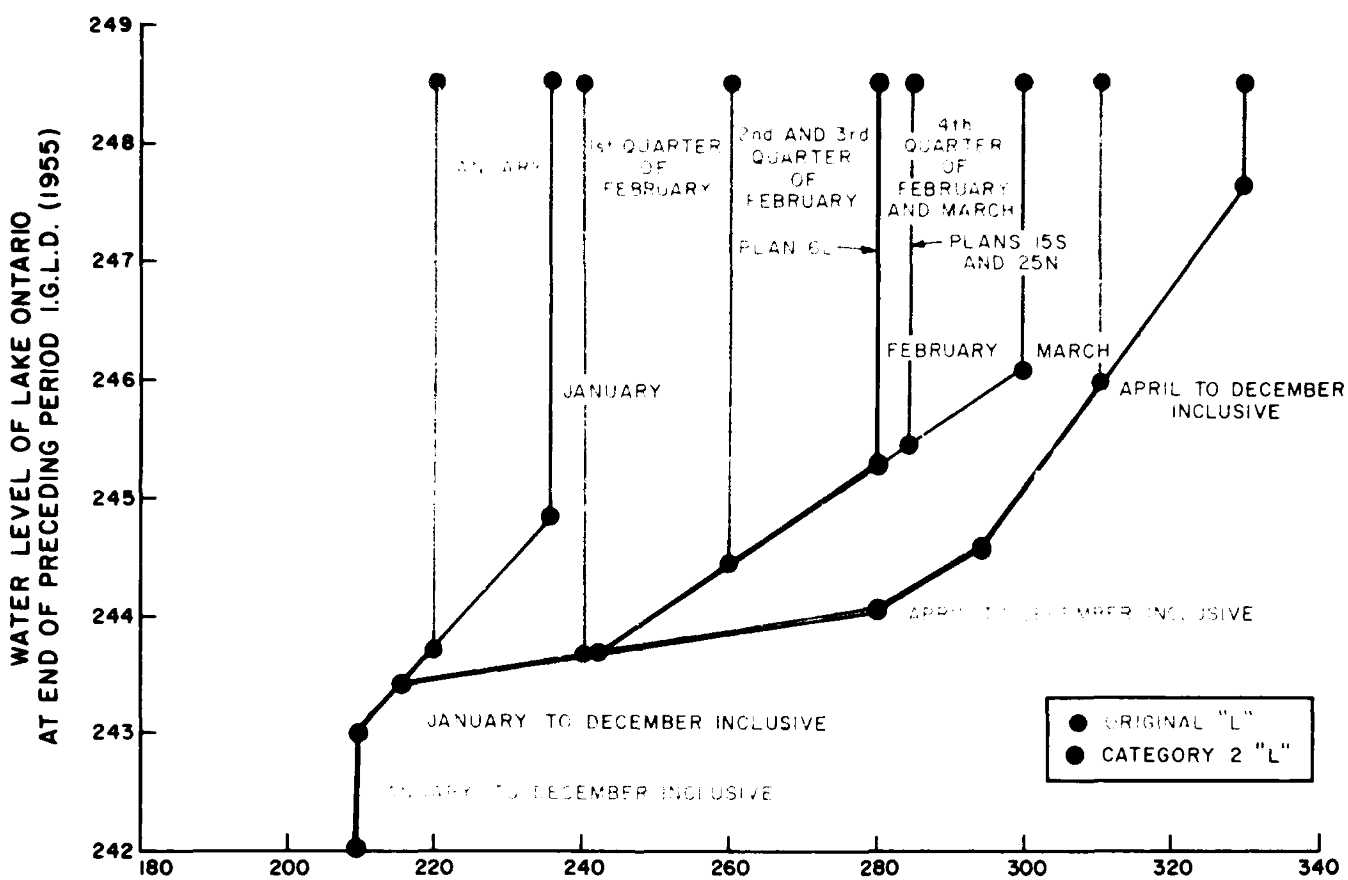


MAXIMUM OUTFLOW LIMITATIONS AS RELATED TO WATER LEVELS

"L" OUTFLOW LIMITATION - REGULATION OF LAKE ONTARIO PLAN 1958-D

FIGURE 15

FIGURE 15



MAXIMUM REGULATED DISCHARGE - 1000 CFS
MAXIMUM OUTFLOW LIMITATIONS AS RELATED TO WATER LEVELS

REGULATION OF LAKE ONTARIO PLAN 1958-D
ORIGINAL AND CATEGORY 2 "L" LIMITATIONS

FIGURE 16

FIGURE 16

AD-A114 582 INTERNATIONAL LAKE ERIE REGULATION STUDY BOARD F/G 13/2
LAKE ERIE WATER LEVEL STUDY. MAIN REPORT.(U)
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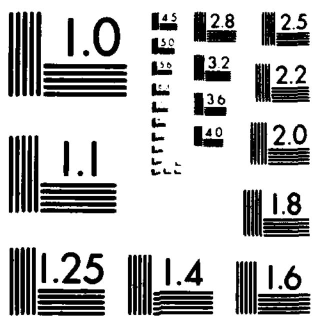


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

4.6.2 "I" Limitation

As noted in Section 4.5.1, the "I" limitation under Plan 1958-D relates to the maximum release of water from Lake St. Louis during the last half of December. This limitation has been waived on numerous occasions by the International St. Lawrence River Board of Control and thus was not employed in the testing of the Category 3 plans as well as the adjusted basis-of-comparison.

4.6.3 "P" Maximum Flow Limitation

During certain periods of the year, the outflow from Lake Ontario is restricted under Plan 1958-D to preproject flows in order to satisfy criteria (c) and (d) of the Commission's Orders of Approval. These criteria are related to the annual spring breakup in Montreal Harbour and the annual flood discharge from the Ottawa River. To duplicate conditions that occurred in the 1970's it was necessary to increase the limiting control numbers employed in Plan 1958-D by 15,000 cfs with application when the outflow from Lake St. Louis exceeds 345,000 cfs. This degree of modification was employed in both the adjusted basis-of-comparison and the Category 3 plans.

4.6.4 "M" Minimum Flow Limitation

Section 4.5.3 notes the minimum outflow criterion to be satisfied by any plan of regulation for Lake Ontario. Table 22 lists the minimum flows which satisfy the requirements under the adjusted basis-of-comparison and Category 3 regulation plans. Due to the low water supplies of the 1960's, the values for January, February, March, and December under the adjusted basis-of-comparison are smaller than those under the basis-of-comparison.

Table 22 - Minimum Permissible Lake Ontario Outflows for Plan 1958-D Under Category 3 (TCFS)

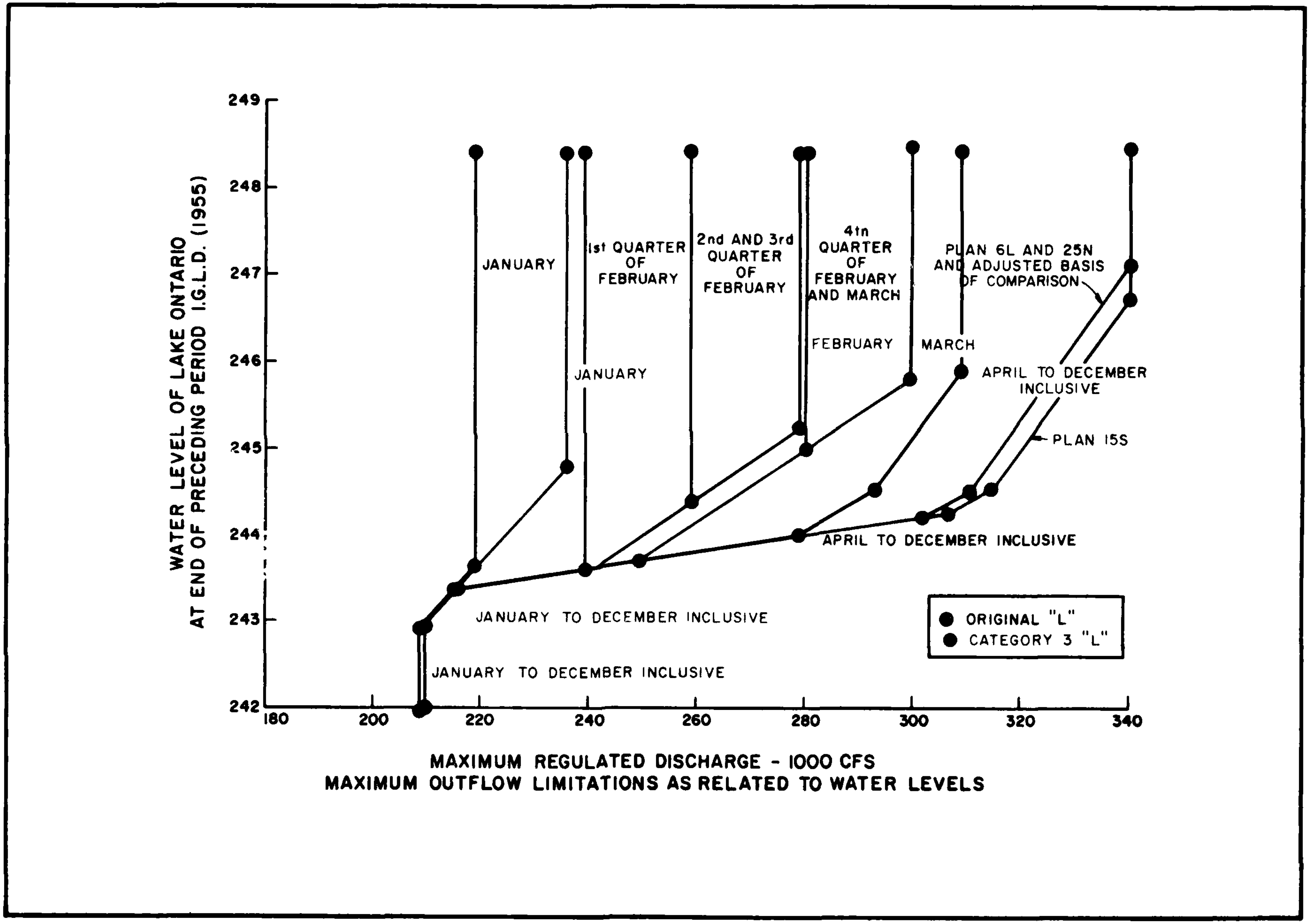
	Adjusted Basis-of-Comparison	Plan 25N	Plan 15S	Plan 6L
Jan	203	200	202	203
Feb	200	200	200	200
Mar	196	195	195	196
Apr	188	188	188	188
May	188	188	188	188
Jun	190	190	190	190
Jul	195	190	190	195
Aug	197	195	195	197
Sep	202	200	202	202
Oct	203	200	202	203
Nov	203	200	202	203
Dec	203	200	202	203

4.6.5 "J" Outflow Limitation

Under Plan 1958-D, the restriction on change in flow between regulation periods is limited to 20,000 cfs. Under the adjusted basis-of-comparison and Category 3 plans, the value has been increased to 45,000 cfs.

4.6.6 "L" Outflow Limitation

Figure 17 shows the "L" limitation curve employed under Plan 1958-D. Superimposed on this plate are the modified conditions for Plans 25N, 15S, and 6L as well as the adjusted basis-of-comparison. The resulting modifications provide for satisfaction of the criteria for the regulation of Lake Ontario over the entire test period (1900-1976).



REGULATION OF LAKE ONTARIO PLAN 1958-D
ORIGINAL AND CATEGORY 3 "L" LIMITATIONS

FIGURE 17

FIGURE 17

Section 5

NIAGARA AND ST. LAWRENCE RIVER REGULATORY AND REMEDIAL WORKS

5.1 General

An array of structural and remedial alternatives in the Niagara and St. Lawrence Rivers was chosen to accommodate a wide range of flows resulting from limited regulation of Lake Erie associated with the three study categories discussed in Section 4. Preliminary engineering designs and cost estimates for regulatory works in the Niagara River and for remedial works in the St. Lawrence River were prepared to assist regulation plan development, to provide a range of discharge capacity versus cost curves, and to form a basis for the evaluation of selected regulation plans presented in Section 6.

5.2 Niagara Works

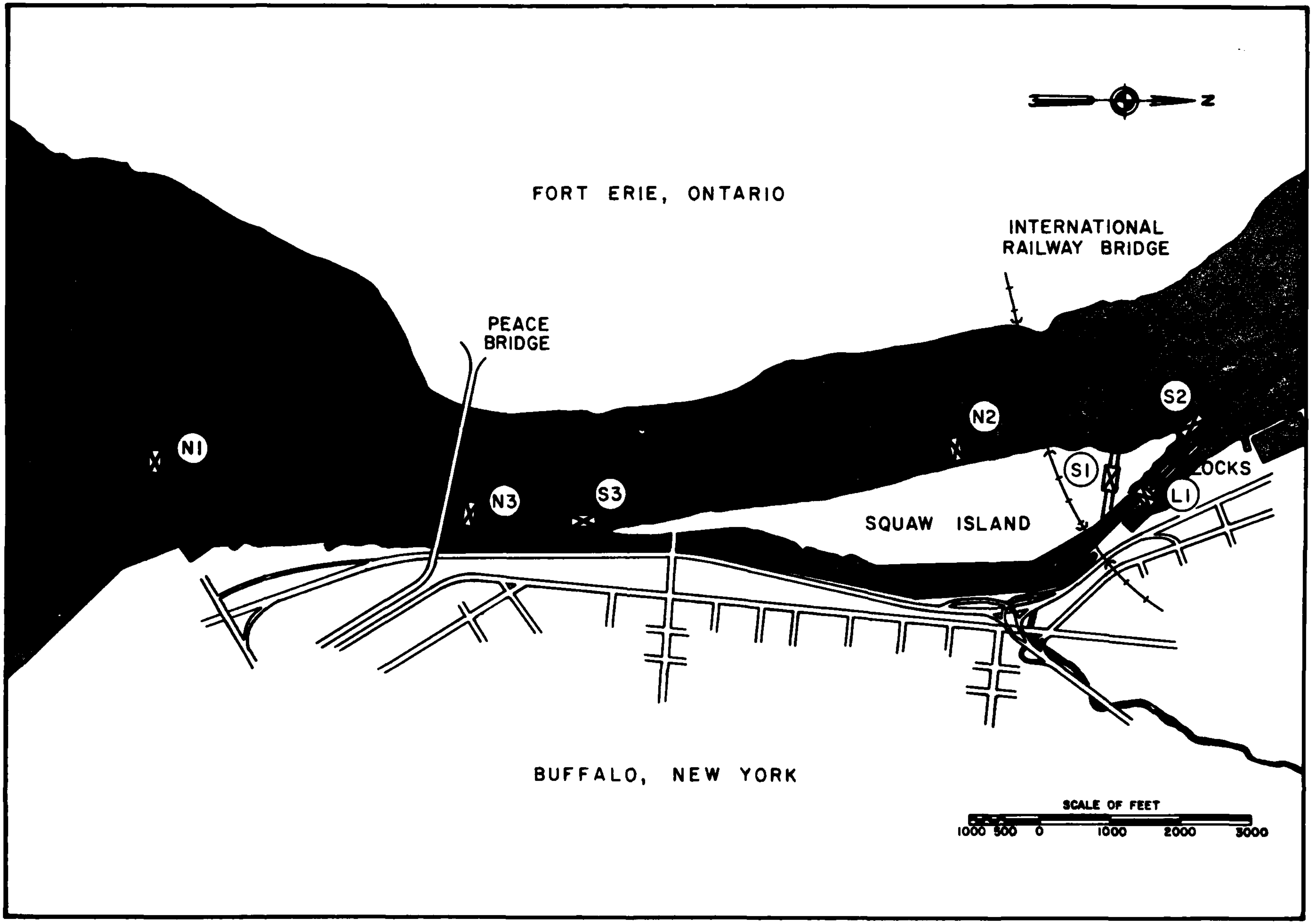
Lowering the high water level of Lake Erie would require an increase in the discharge capacity of the Niagara River. Regulatory works either in or contiguous to the Niagara River would be required to implement limited regulation of Lake Erie. As noted in Section 4.5, three regulation plans were selected for detailed evaluation, namely, Niagara River Plan 25N, Black Rock Canal-Squaw Island Plan 15S and Black Rock Lock Plan 6L. The locations of the regulatory works required to implement each of the selected plans are shown on Figure 18. The following is a summary of the selected regulatory works alternatives.

5.2.1 Niagara River Structure

Niagara River Plan 25N would permit an increase of 25,000 cfs in Lake Erie outflows. The plan would require extensive excavation from the riverbed, principally rock, in the vicinity of the Peace Bridge. A multi-gated control structure extending out into, but not fully across, the river would also be necessary in order to offset the effect of this channel excavation when increased Lake Erie outflows are not required.

The section of the Niagara River in the vicinity of the Peace Bridge provides substantial natural regulation due to its existing restricted dimensions. The area to be excavated which is adjacent to the Bird Island pier, would extend from approximately 1,000 feet upstream from the Peace Bridge to approximately 2,400 feet downstream, would vary in width from about 700 feet to 950 feet, and would vary up to 17 feet in depth.

The multi-gated control structure would be located adjacent to the Bird Island pier and approximately 300 feet downstream from the existing Peace Bridge. The structure would extend approximately 600 feet into the river and would contain six remote-controlled submersible tainter gates, 40 feet high by 75 feet wide. The structure would be equipped for year-round operation. Construction of the structure would require extensive cofferdams and would be hampered by the lack of adequate land access. Approximately 1,200,000 cubic yards of predominently rock excavation would be required,



NIAGARA RIVER REGULATORY WORKS ALTERNATIVES

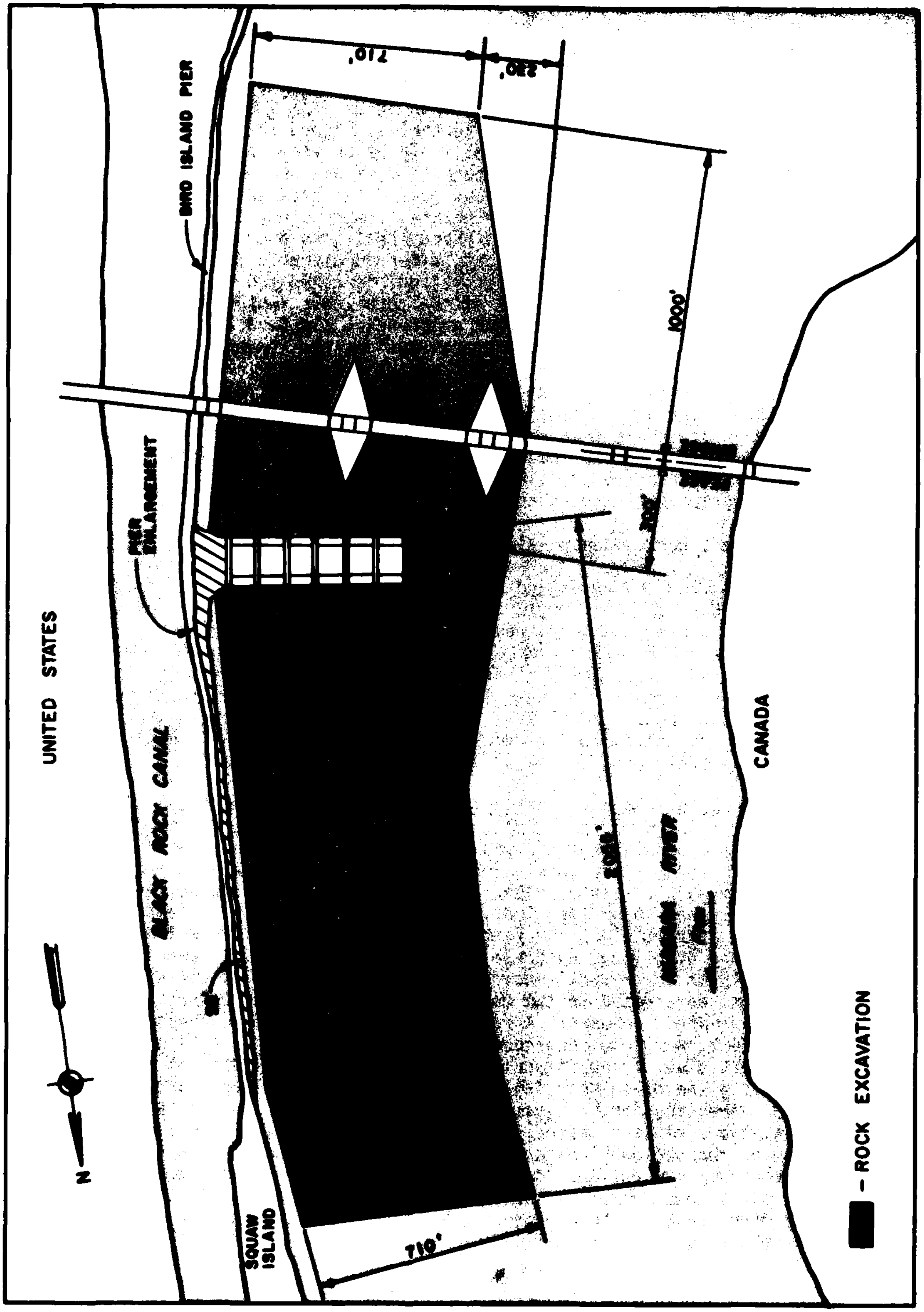
FIGURE 18

including 140,000 cubic yards for the control structure foundation. Shore protection along the Canadian shoreline would be provided at critical locations upstream from the control structure to mitigate the adverse impact of the increased velocity and water surface profile in this area. The total first cost of the proposed control structure, compensatory dredging and appurtenant works, based on July 1979 price levels, is approximately $111.4 million. The corresponding annual cost, after adjustments for finance, operation and maintenance, and administration, is estimated to be $11.6 million. The computed present worth of the total cost, which consists of all costs including finance, operation and maintenance, is $134.2 million. These costs are preliminary estimates and do not reflect consideration for sophisticated ice control measures which may be necessary to permit the construction and operation of this type of control structure at this location. An assessment of the feasible operation of this structure during severe ice runs from Lake Erie would require considerable detailed design effort. Figure 19 shows the location of the proposed control structure and the limits of compensatory dredging required to implement Plan 25N. Figure 20 shows a longitudinal cross section through the control structure.

5.2.2 Black Rock - Squaw Island Structure

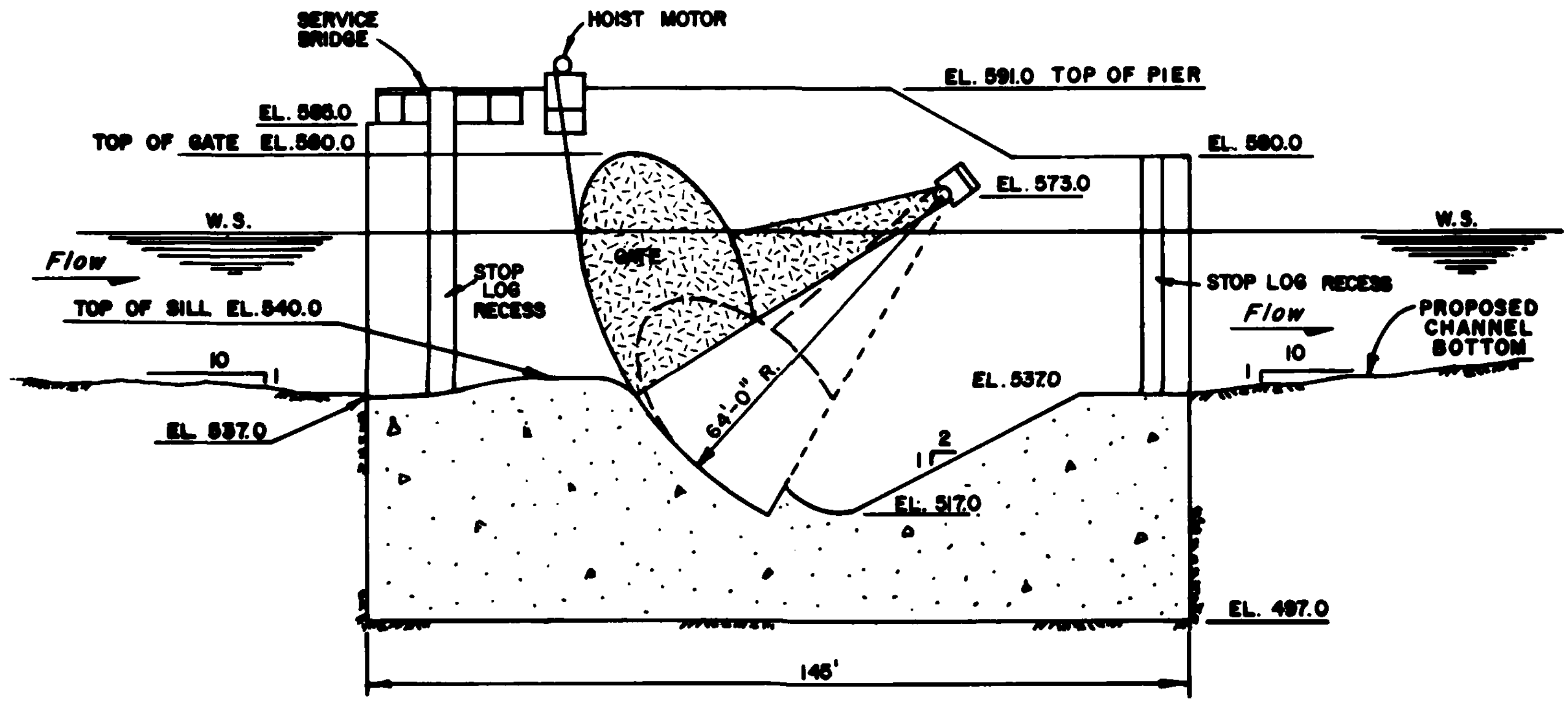
Black Rock Canal-Squaw Island Plan 15S considers a lesser increase in Lake Erie outflow. The plan would provide an increased Lake Erie design outflow of 15,400 cfs. However, navigational operating constraints in the Black Rock Canal would reduce the design outflow to a net annual discharge of approximately 9,600 cfs. The alignment of the diversion channel across the downstream end of Squaw Island was similar to that previously considered in the International Great Lakes Levels Board Report dated December 1973. However, environmental and social concerns suggest selection of an alternative site adjacent to the existing Black Rock Lock.

Plan 15S would require construction of a control structure and diversion channel along an alignment parallel to and adjacent to the existing Black Rock Lock. The control structure would be located immediately adjacent to the lock's downstream mitre gate. The structure would contain a remote-controlled submersible tainter gate, 34 feet high by 75 feet wide, and would be equipped for year-round operation. A diversion channel, 160 feet wide, would extend approximately 1,700 feet along the lock walls. The 1 on 2.5 westerly channel sideslope, upstream of the control structure, would be protected with riprap to prevent erosion. An earth dike, with a top width of 10 feet, would be constructed on the upstream west side of the diversion channel to provide adequate freeboard. A rock dike, with 1 on 2 sideslopes and a top width of 10 feet, would be constructed across the open water area on the downstream west side of the diversion channel. Bank protection at critical locations along the Black Rock Canal would be provided as necessary. Guard cells with connecting footbridges would be constructed at the upstream entrance to the diversion channel to prevent accidental entry by commercial navigation or recreational boaters. A traffic control system would be provided at the upstream entrance to the Black Rock Canal to warn vessels that the canal may become dangerous during the operation of the control structure. The total first cost of the proposed control structure, diversion channel and appurtenant works, based on July 1979 price levels, is approximately $19.6



NIAGARA RIVER PLAN 25N

FIGURE 19



CENTERLINE PROFILE OF CONTROL STRUCTURE

NIAGARA RIVER PLAN 25N

FIGURE 20

million. The corresponding annual cost, after adjustments for finance, operation and maintenance, and administration, is estimated to be $2.0 million. The computed present worth of the total cost, which consists of all costs including finance, operation and maintenance, is $22.5 million. Figure 21 shows the location of the proposed control structure and diversion channel required to implement Plan 15S. Figure 22 shows a longitudinal cross section through the control structure.

5.2.3 Black Rock Lock Structure

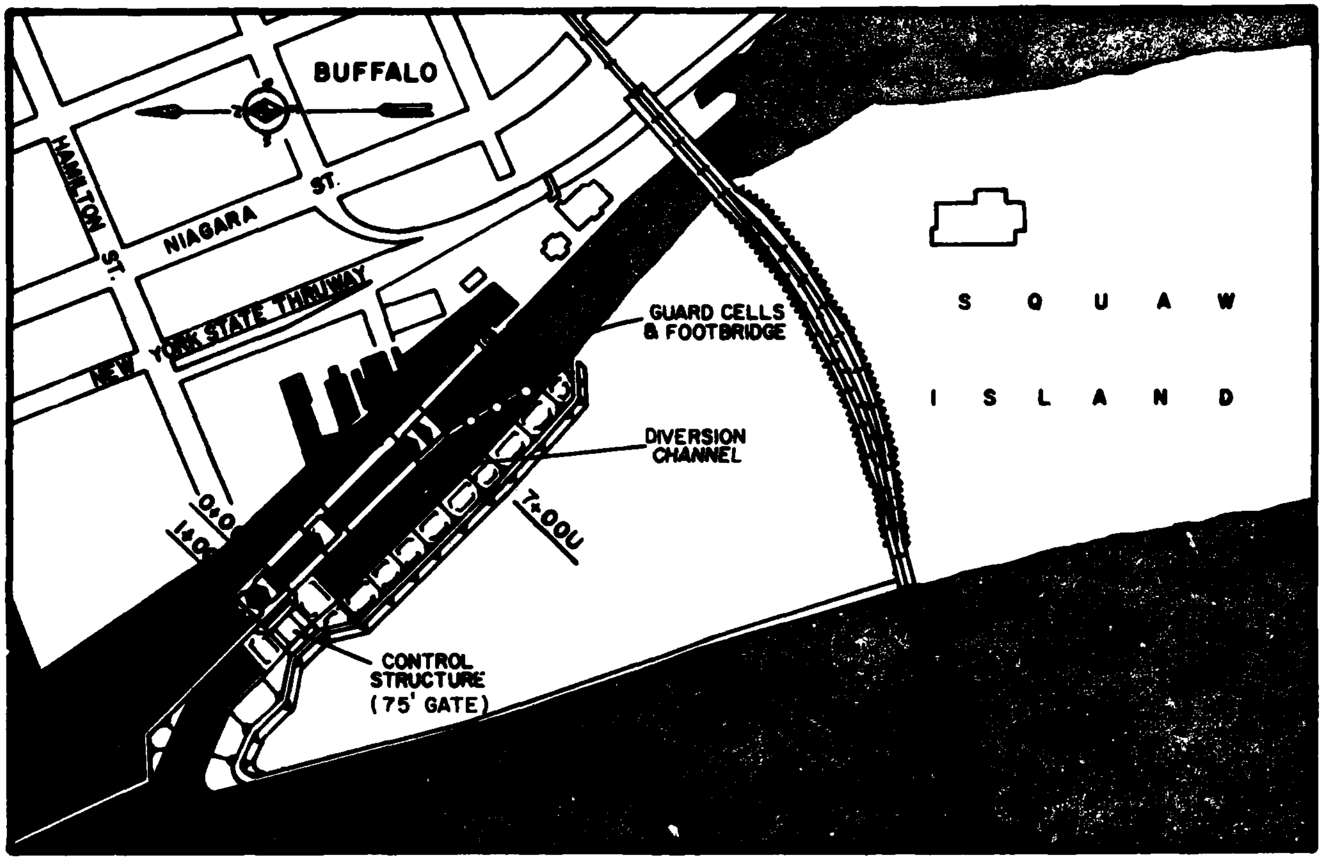
Black Rock Lock Plan 6L addresses a low range increase in Lake Erie outflow. The plan would provide an increased Lake Erie design outflow of 6,800 cfs. However, operating constraints necessary to accommodate seasonal navigation requirements in the Black Rock Canal would reduce the design outflow to a net annual discharge of approximately 3,700 cfs.

Plan 6L requires the modification of the existing Black Rock Lock. A control structure, consisting of a pair of hydraulically operated sector gates, would be constructed in the upstream approach channel adjacent to the existing upper guard gate. In a closed position, the 33-foot high sector gates would span the 70-foot wide lock chamber. They would rotate horizontally into wall recesses to provide varying discharge capacities. During time periods set aside for navigation, the sector gates would recess flush into the chamber walls. To achieve the design capacity required by Plan 6L, the sector gates would be opened to a 30-foot width and controlled in accordance with a strict seasonal operating plan. Under these conditions, no remedial measures, such as bank protection along the canal, would be required. The total first cost of the proposed control structure and appurtenant works, based on July 1979 price levels, is approximately $10.3 million. The corresponding annual cost, after adjustments for finance, operation and maintenance, and administration, is estimated to be $1.2 million. The computed present worth of the total first cost, which consists of all costs including finance, operation and maintenance, is $13.8 million. A typical sector gate layout and transverse cross section are shown on Figures 23 and 24 respectively.

5.2.4 Design Considerations

The effects of ice from Lake Erie on each plan's regulatory works and some of the problems which would likely result were briefly considered. Due to the complexity and indeterminate nature of the ice problem, a detailed engineering evaluation was not undertaken because of the infeasibility of the Study.

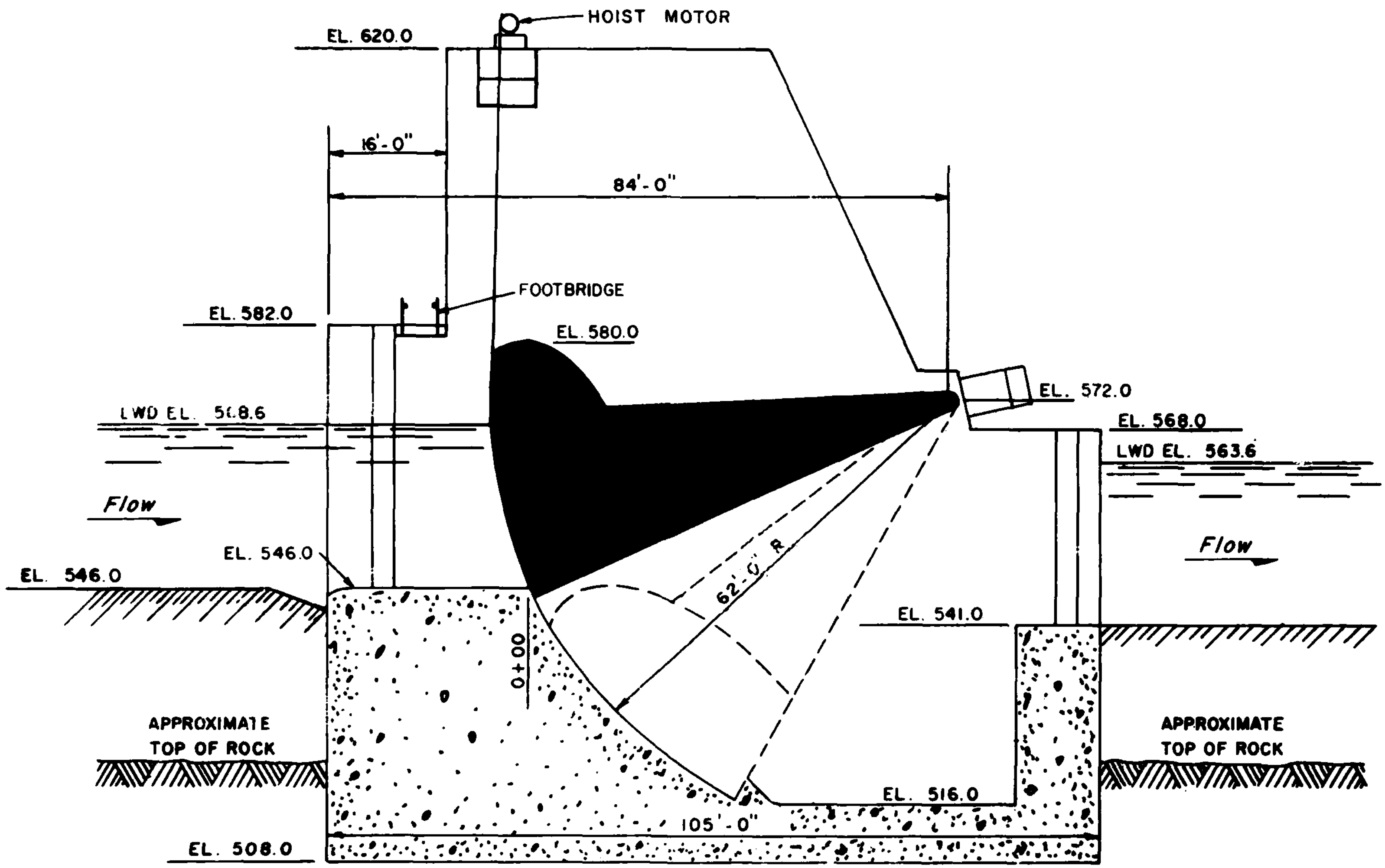
An operating plan was developed to be used in conjunction with Plan 15S and another, somewhat more restrictive plan to be used with Plan 6L. Each of these operating plans would substantially limit the daily diversion flows on a seasonal basis and, in so doing, accommodate the overall commercial navigation and recreational boating requirements in the Black Rock Channel.



INDICATES RIPRAP

BLACK ROCK CANAL - SQUAW ISLAND PLAN 15S

FIGURE 21

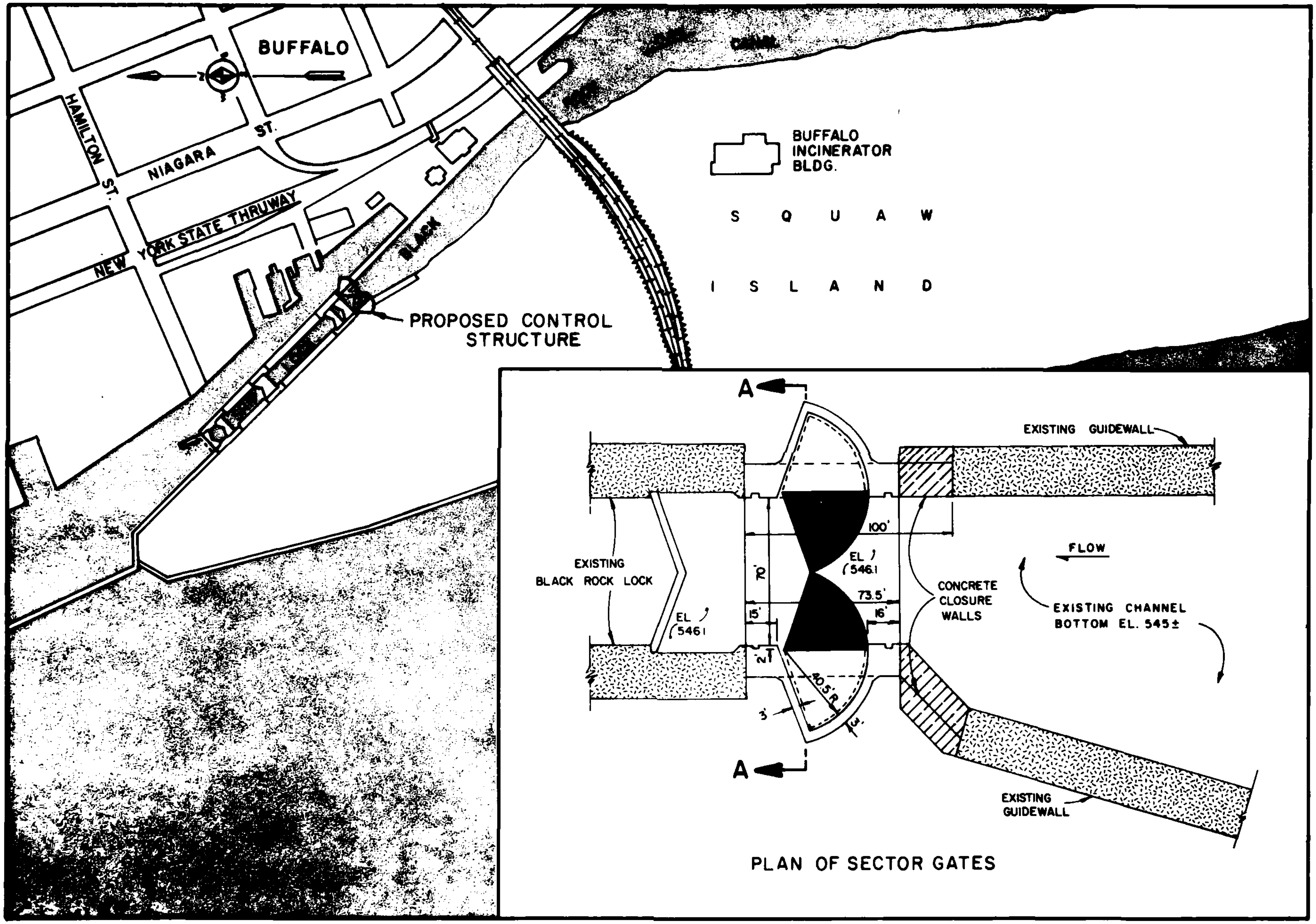


CENTERLINE PROFILE OF CONTROL STRUCTURE

BLACK ROCK CANAL - SQUAW ISLAND PLAN 15S

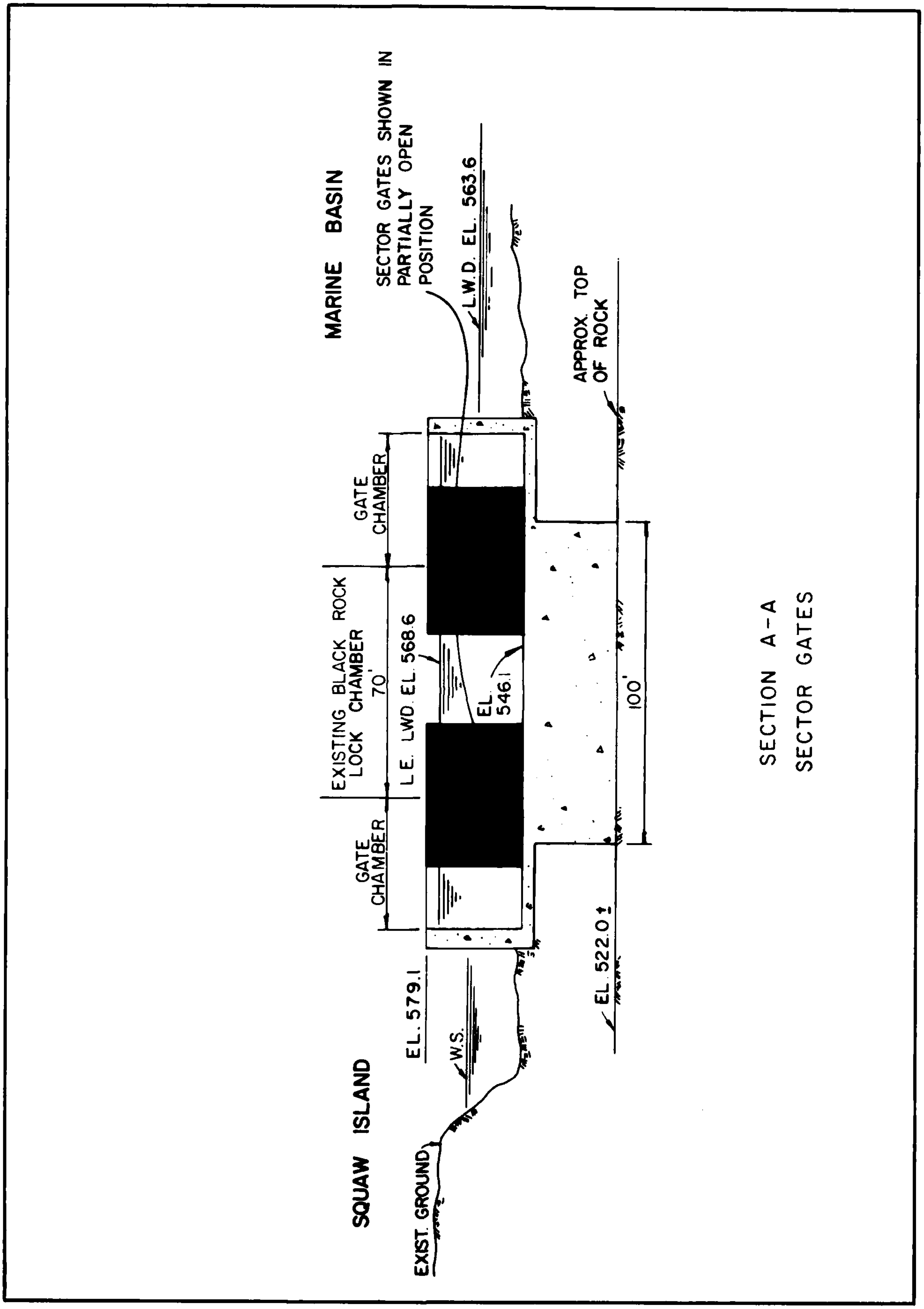
FIGURE 22

FIGURE 22



BLACK ROCK LOCK PLAN 6L

FIGURE 23



SECTION A-A
SECTOR GATES

BLACK ROCK LOCK PLAN 6L

FIGURE 24

5.3 St. Lawrence River Remedial Works

Limited regulation of Lake Erie would result in an increase in the frequency and duration of high Lake Ontario outflow. In the International Reach of the St. Lawrence River, dredging would be required in certain sections of the river in order to increase its discharge capacity. In the Canadian Reach, channel enlargement at Lachine Rapids would be required to mitigate flooding in Lake St. Louis. In this reach, much information with respect to optimum areas for dredging was available from earlier Canada-Quebec flood studies of the Montreal area. The locations of the remedial works that would be required in the International and Canadian Reaches, are shown in Figures 25 and 26, respectively. The following is a summary of the required remedial works.

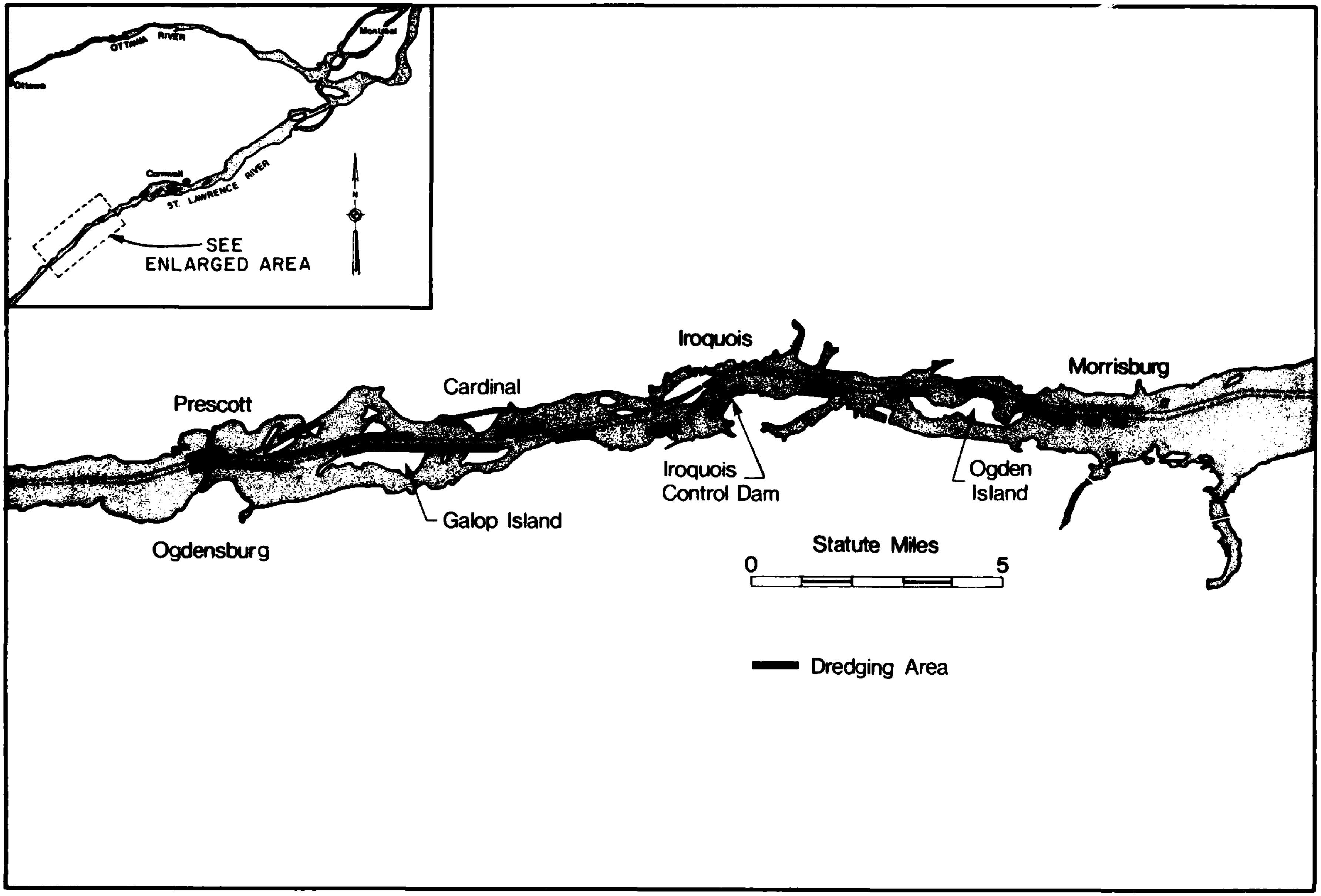
5.3.1 International Reach

The International Reach of the St. Lawrence River extends from Kingston, Ontario, on Lake Ontario to an area just downstream from the Long Sault Dam and Moses-Saunders Powerhouse. To maintain existing water level profiles under increased Lake Ontario outflow conditions and not exceed a maximum velocity of 4 feet/second in the navigation channels in accordance with a requirement in the Orders of Approval, dredging will be required in certain reaches of the river. It should be noted that channel design velocities are currently exceeded in some restricted areas of the shipping channel under existing flow conditions. During the high supply period of the early 1970's, the maximum velocity requirement was often exceeded for sustained periods of time in order to discharge outflows higher than the channel was designed for.

In order to differentiate between the Lake Ontario outflow requirements due to Lake Erie regulation and that due to the high water supplies of the 1970's, the lake levels and outflows under the three Lake Erie plans were compared with the adjusted basis-of-comparison under Category 3. The development of Category 3 plans is described in detail in Section 4.6. It was noted that, in order to handle the high supplies of the 1970's, channel excavation to provide an additional capacity of 4,000 cfs would be required. This capacity increase would also be adequate to handle Lake Erie Regulation Plan 6L.

In order to implement Lake Erie Regulation Plan 25N, a capacity increase of about 5,000 cfs would be required. Plan 15S would require a capacity increase of about 6,000 cfs. Since Plan 25N uses the capacity of a Niagara River structure year-round, its annual distribution of increased flow from Lake Erie is more uniform than that of either Plan 6L or 15S. As a result, Plan 25N would require lesser capacity increase in the St. Lawrence River than would Plan 15S. This illustrates that the sequence and magnitude of the supplies to Lake Ontario are important factors in determining channel enlargements.

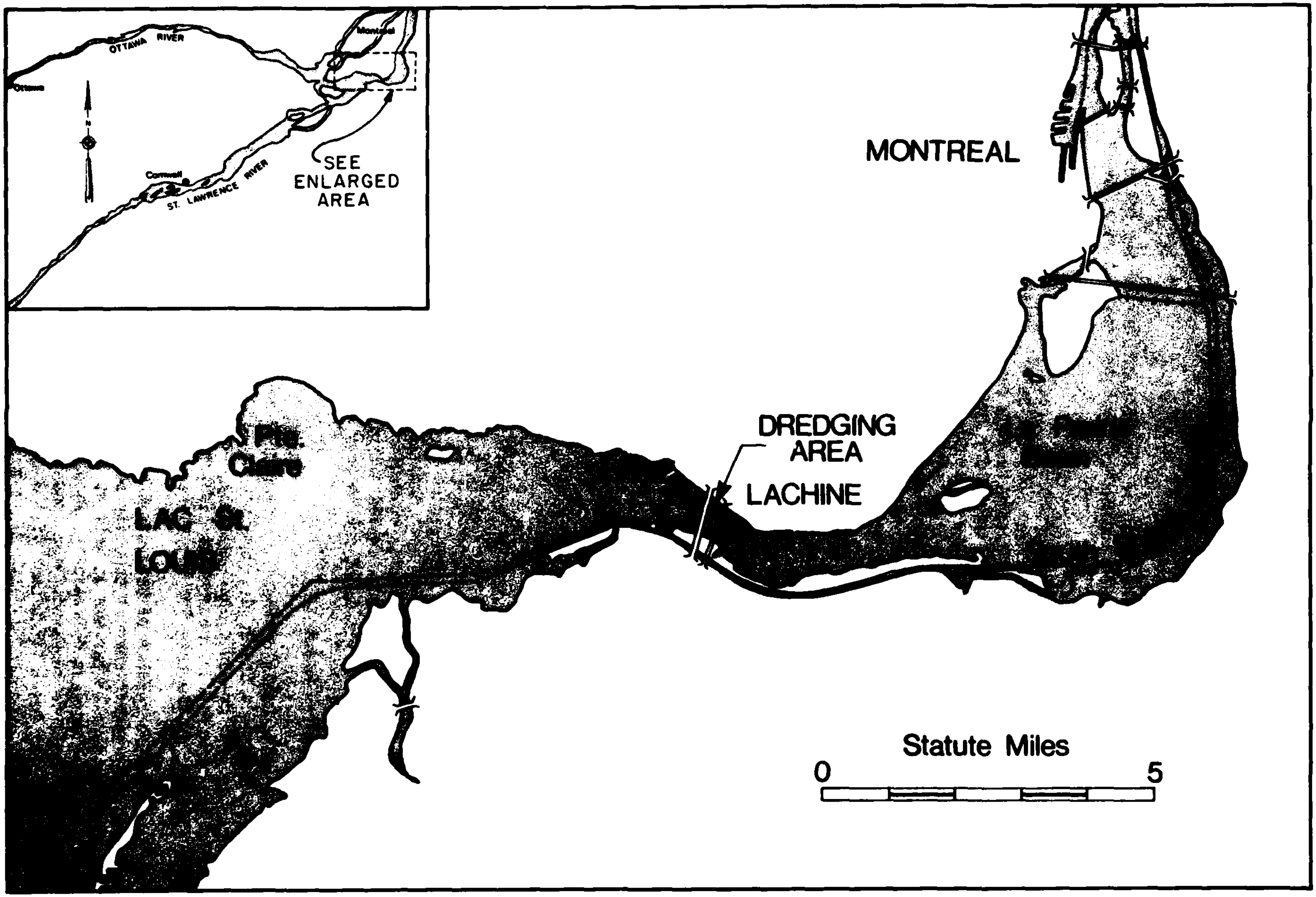
In order to provide the additional capacities, channel excavation would be required in the reach from Prescott, Ontario - Ogdensburg, NY, to Morrisburg, Ontario. The locations of the required dredging are shown in Figure 25. By restricting excavation to glacial till material in the sides



ST. LAWRENCE RIVER REMEDIAL WORKS - INTERNATIONAL REACH

FIGURE 25

FIGURE 25



ST. LAWRENCE RIVER REMEDIAL WORKS CANADIAN REACH

FIGURE 26

FIGURE 26

of the navigation channel rather than in the hard bedrock of the bottom of the channel, sufficient conveyance capacity could be provided at a lower cost.

To provide for the required increase in capacity of 4,000 cfs under the adjusted basis-of-comparison and Plan 6L, the amount of excavation would be about 3 million cubic yards with a construction period of 2 years. All dredged material would be disposed of on dry land to avoid contamination of waters. The total first cost of the excavation, based on July 1979 price levels, is approximately $30.0 million. The corresponding annual cost after adjustments for finance, operation and maintenance, and administration, is estimated to be $2.9 million. The computed present worth of the total cost, which consists of all costs and operation and maintenance, is $33.6 million.

To provide for an increase in capacity of 5,000 cfs as called for under Plan 25N, the amount of excavation would be about 3.8 million cubic yards with a construction period of about 2 years. As for the Plan 6L and the adjusted basis-of-comparison excavation, all dredged material would be disposed of on dry land to avoid contamination of waters. The total first cost of the excavation, based on July 1979 price levels, is approximately $38.0 million. The corresponding annual cost, after adjustments for finance, operation and maintenance, and administration, is estimated to be $3.4 million. The computed present worth of the total cost, which consists of all costs and operation and maintenance, is $39.1 million.

To provide for an increase in capacity of 6,000 cfs as called for under Plan 15S, the amount of excavation would be about 4.5 million cubic yards. The first cost is approximately $45.0 million. The annual cost and present worth are estimated to be $4.3 million and $50.2 million, respectively.

In Section 5.2, it was noted that detailed engineering design and evaluation would be necessary to insure feasible operation of the Niagara River structure under ice condition. In the case of remedial measures in the International Reach of the St. Lawrence, identification of the exact location and quantity of the required channel excavation would require comprehensive design studies including extensive hydraulic modeling of the channel in question. Therefore, the location and extent of the required excavation stated above should be viewed as preliminary estimates only.

5.3.2 Canadian Reach

The Canadian Reach of the St. Lawrence River extends downstream from Cornwall, Ontario - St. Regis, New York to sea level at Father Point, Quebec. In order to provide additional capacity for combined Lakes Erie and Ontario regulation, channel enlargement at Lachine Rapids would be required to mitigate flooding in the Lake St. Louis area.

Based on the results of Category 3 study, it was determined that the required increase in channel capacity at Lachine is 15,000 cfs for the adjusted basis-of-comparison as well as the three Lake Erie plans. To provide for this increase in capacity, about 1 million cubic yards of channel excavation would be required. The location of the excavation is shown in Figure 26. The total first cost of the excavation, based on July 1979 price

levels, is approximately $41.9 million. The corresponding annual cost, after adjustments for finance, operation and maintenance, and administration, is estimated to be $4.0 million. The computed present worth of the total cost, which consists of all costs, including finance, operation and maintenance, is $46.5 million.

5.4 Cost Summary of Regulatory and Remedial Works

Limited regulation of Lake Erie would require construction of regulatory works at the head of the Niagara River. To implement a combined Lakes Erie and Ontario Regulation Plan, remedial works in the St. Lawrence River would also be required. The nature and extent of these works depend on the regulation plan selected.

Table 23 is a summary of the costs of regulatory and remedial works relative to the regulation plans investigated. These costs are not based on detailed design studies but are preliminary estimates for the purposes of determining project feasibility.

Table 23 - Cost Summary of Regulatory and Remedial Works

Cost Relative to Regulation Plan	Location: Niagara River	St. Lawrence River: International Reach	St. Lawrence River: Canadian Reach	Total
A. Plan 6L				
Present Worth ($$10^6$)	13.8	33.6	46.5	93.9
Average Annual ($$10^6$)	1.2	2.9	4.0	8.1
B. Plan 15S				
Present Worth ($$10^6$)	22.5	50.2	46.5	119.2
Average Annual ($$10^6$)	2.0	4.3	4.0	10.3
C. Plan 25N				
Present Worth ($$10^6$)	134.2	39.1	46.5	219.8
Average Annual ($$10^6$)	11.6	3.4	4.0	19.0
D. Adjusted Basis-of-Comparison				
Present Worth ($$10^6$)	-	33.6	46.5	80.1
Average Annual ($$10^6$)	-	2.9	4.0	6.9

The costs shown for the St. Lawrence remedial works also reflect those which would be required for channel improvements to accommodate the high water supplies of the 1970's while not violating the Commission's criteria for the regulation of Lake Ontario.

Section 6

EVALUATION OF REGULATION PLANS

6.1 Hydrologic Evaluation

6.1.1 Introduction

The two primary hydrologic factors evaluated are lake levels and outflows. Analysis of these two factors includes the consideration of their maximum, mean, and minimum monthly values, range, duration, and seasonal distribution. Various criteria expressed in these hydrologic terms are used to evaluate the regulation plans developed herein. These criteria reflect the Commission's Orders of Approval on the regulated lakes. For the currently unregulated lakes, similar criteria were developed. The evaluation involves the determination of the degree to which each regulation plan meets such criteria in comparison to the basis-of-comparison, assuming all to be in effect during the period 1900-1976. The hydrologic evaluation of selected plans with respect to the criteria and objectives for regulation is discussed below. The Category 1 evaluation for all lakes and the Category 2 and 3 evaluations for Lake Ontario are also presented. Table 24 is a summary of a hydrologic evaluation of selected Lake Erie regulation plans under Category 1. Table 45 is a similar comparison for Categories 2 and 3.

6.1.2 Category 1 Plans

Category 1 Plans consist of Lake Erie regulation constrained by the present Orders of Approval, with the present channel limitation of the St. Lawrence River, and Lake Ontario regulated in accordance with Plan 1958-D and with discretionary deviations as they occurred over time.

Lake Superior:

Criterion (a). The Commission's 1979 Orders require that the control works shall be operated so that the regulated monthly mean level of Lake Superior not exceed elevation 602.0 or fall below elevation 598.4.

The maximum and minimum monthly mean levels of Lake Superior under each of the plans selected for detailed evaluation are shown on Table 24. The frequency of occurrence of high and low levels is also of considerable importance with respect to this criterion. Tables 25 and 26 compare the frequency under each of the plans with the basis-of-comparison.

Table 24 shows that limited regulation of Lake Erie would result in no change in the Lake Superior maximum stage. In all cases, the criterion not to exceed 602.0 would be satisfied. However, Table 24 shows that the extreme low levels under all plans would be lowered somewhat by the regulation of Lake Erie but would remain above 598.4 feet. Hence, the criterion would not be satisfied to the same degree as under the basis-of-comparison.

Table 24 - Summary of Hydrologic Evaluation of Lake Erie Regulation Plans Under Category 1

	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
LAKE SUPERIOR				
Mean	600.44	600.43	600.41	600.37
Maximum	601.93	601.93	601.93	601.93
Minimum	598.69	598.68	598.65	598.62
Range	3.24	3.25	3.28	3.31
LAKES MICHIGAN-HURON				
Mean	578.27	578.24	578.18	578.05
Maximum	581.15	581.09	580.99	580.75
Minimum	575.47	575.45	575.42	575.36
Range	5.68	5.64	5.57	5.39
LAKE ERIE				
Mean	570.76	570.67	570.53	570.17
Maximum	573.60	573.45	573.18	572.53
Minimum	568.09	568.07	568.02	567.84
Range	5.51	5.38	5.16	4.69
LAKE ONTARIO (with deviation)				
Mean	244.61	244.64	244.65	244.63
Maximum	247.37	247.39	247.56	247.50
Minimum	241.81	241.74	241.59	241.38
Range	5.56	5.65	5.97	6.12

Table 25 - Monthly Mean Water Levels of Lake Superior, 1900-1976
Number of Occurrences Above Level Shown

Monthly Mean Level	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
602.0	0	0	0	0
601.9	1	1	1	1
601.8	1	1	1	1
601.7	2	2	2	2
601.6	9	8	5	4
601.5	18	19	16	11
Maximum	601.93	601.93	601.93	601.93

Table 26 - Monthly Mean Water Levels of Lake Superior, 1900-1976
Number of Occurrences Below Level Shown

Monthly Mean Level	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
All Months				
600.0	211	218	225	247
599.5	49	49	56	61
599.0	6	7	7	9
598.5	0	0	0	0
Minimum	598.69	598.68	598.65	598.62
April - November				
600.0	85	90	93	103
599.5	18	18	23	25
599.0	2	2	2	3
598.5	0	0	0	0
598.0	0	0	0	0
Minimum	598.70	598.69	598.66	598.63

As noted, the freqency of occurrence of high and low levels are also important. Table 25 shows a reduction in the frequency of occurrence of all stages above 601.6 feet under all three plans being evaluated, when compared to the basis-of-comparison. Table 26 also shows an increase in the frequency of levels below elevation 600.0 feet (LWD on Lake Superior). The magnitude of lowering as well as the frequency of low water levels become greater as the outflow from Lake Erie increases from Plan 6L to Plan 25N.

Criterion (b). The Commission's Orders specify, to guard against unduly high stages of water in the lower St. Marys River, the excess discharge at any time over and above that which would have occurred at a like stage of Lake Superior prior to 1887, shall be restricted so that elevation of the water surface immediately below the locks shall not be greater than 582.9 feet.

In the test of the Lake Superior portion of the plans over the period 1900-1976, the maximum stage at the U. S. Slip gage, below the lock is indicated on Table 27. Table 27 shows that criterion (b) which has been satisfied by the basis-of-comparison would also be satisfied by all three plans.

Table 27 - Maximum Stage - U.S. Slip

	Elevation (feet)
Basis-of-Comparison	582.32
Plan 6L	582.28
Plan 15S	582.24
Plan 25N	582.09

Criterion (c). The maximum open-water (May-November) limitation on outflow from Lake Superior is equivalent to the discharge capacity of the Compensating Works plus 65,000 cfs.

This maximum outflow limitation was also applicable under the basis-of-comparison and was employed in all plans presented herein. Table 28 compares the results of the plans with those of the basis-of-comparison.

Table 28 shows that the maximum flow out of Lake Superior under the three plans being evaluated are identical to that which occurred under the basis-of-comparison. The table further shows a reduction in the frequency of occurrence of these high flows.

It should be noted, that the Commission's 1979 Orders also specify that "whenever the monthly mean level of the lake (Lake Superior) is less than 600.5 feet, the total discharge permitted shall be no greater than that which would have occurred at the prevailing stage of Lake Superior prior to 1887." This requirement was not employed in the development and testing of Plan 1977

Table 28 - Monthly Mean Outflow from Lake Superior, May-November 1900-1976
Number of Occurrences Above Outflow Shown

Monthly Mean Outflows (Thousands of cfs)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
125	0	0	0	0
120	3	3	3	3
115	43	43	40	37
110	68	68	66	64
105	94	94	92	84
100	133	128	125	126
Maximum	123,000	123,000	123,000	123,000

Table 29 - Monthly Mean Outflow from Lake Superior, December-April
1900-1976, Number of Occurrences Above Outflow Shown

Monthly Mean Outflows (Thousands of cfs)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
85	3	3	3	5
84	8	7	7	12
83	11	11	11	16
82	14	14	14	19
81	27	27	26	30
80	42	42	41	47
Maximum	86,000	86,000	86,000	87,000

and hence has not been evaluated herein. However, it should also be noted that data shown on Tables 26 and 30 show very little variance on Lake Superior due to limited regulation of Lake Erie. Hence this criterion would be satisfied to the same extent as satisfied by the basis-of-comparison.

Criterion (d). The maximum winter outflow (December-April) from Lake Superior shall not be greater than 85,000 cfs.

This maximum outflow limitation was applicable under the basis-of-comparison as well as under the three regulation plans presented. Table 29 compares the results of the plans with the basis-of-comparison.

The table shows that the maximum flow out of Lake Superior under the three plans is essentially the same as under the basis-of-comparison. However, it should be noted that under Plan 25N there is an increase in the frequency of occurrence of these high flows.

Criterion (e). The minimum outflow from Lake Superior shall not be less than 55,000 cfs.

The minimum outflow from Lake Superior under all three plans has been set at 55,000 cfs. Table 30 compares the frequency of flows below 65,000 cfs. The table shows a decrease in the frequency of low flow under two of the plans (Plan 15S and Plan 25N).

Table 30 - Monthly Mean Outflow from Lake Superior 1900-1976
Number of Occurrences Below Outflow Shown

Monthly Mean Outflows (Thousands of cfs)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
65,000	155	159	148	152
58,000	155	159	148	152
55,000	0	0	0	0

Table 31 - Monthly Mean Water Levels of Lakes Michigan-Huron, 1900-1976
Number of Occurrences Above Level Shown

Monthly Mean Level (Feet)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
581.4	0	0	0	0
581.0	4	2	0	0
580.6	17	13	11	6
580.2	35	33	29	18
579.8	69	65	51	37
579.4	144	136	125	83
579.0	256	244	224	184
Maximum Level	581.15	581.09	580.99	580.75

Lakes Michigan-Huron: The following paragraphs describe the evaluation of effects of the three plans on Lakes Michigan-Huron, employing criteria formulated by the Board for this purpose.

Criterion (a). Consistent with other requirements, reduce the frequency of occurrence of high Lakes Michigan-Huron levels.

Table 24 indicates that all three regulation plans reduce the maximum stage of Lakes Michigan-Huron, in comparison to that which would occur under the basis-of-comparison. Table 31 compares the frequency of occurrence above elevation 579.0 feet. All plans show a reduction in the frequency, with maximum reduction occurring under Plan 25N. All plans are an improvement over the basis-of-comparison.

Criterion (b). Consistent with other requirements, reduce the frequency of occurrence of low Lakes Michigan-Huron levels, especially during the navigation season (April-November).

Table 32 indicates that all three plans reduce the minimum stage and increase the frequency of occurrence of levels below low water datum on Lakes Michigan-Huron (576.8 feet), in comparison to the basis-of-comparison.

Lake Erie: The following paragraphs describe the evaluation of effects of the various plans on Lake Erie employing criteria formulated for this purpose.

Criterion (a). Consistent with other requirements, reduce the frequency of occurrence of high Lake Erie levels.

Table 33 indicates that all three plans lower the maximum stage and reduce the frequency of occurrence of high levels. This lowering amounts to 1.07 feet under Plan 25N; 0.42 foot under Plan 15S; and 0.15 foot under Plan 6L. The frequency of occurrences of high levels (above 572.0 feet) was reduced for all plans.

Criterion (b). Consistent with other requirements, reduce the frequency of occurrence of low Lake Erie levels, especially during the navigation season (April-November).

The broad objective of the Study was to provide the maximum reduction in the frequency of occurrence of above normal Lake Erie levels, while maintaining as near as possible the long-term mean level and the frequency of occurrence of below normal levels. Table 34 shows that the minimum stage would be reduced and the frequency of occurrence of low levels would be increased under all three plans, in comparison to the basis-of-comparison. The table shows a lesser impact during the navigation season than during the "all months" period.

Lake Ontario: The criteria and supplementary requirement stated hereunder have been extracted directly from the 1963 report entitled "Regulation of Lake Ontario Plan 1958-D," by the International St. Lawrence

Table 32 - Monthly Mean Water Levels of Lakes Michigan-Huron, 1900-1976
Number of Occurrences Below Level Shown

Monthly Mean Level (Feet)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
April-November				
576.8 LWD	40	44	48	59
576.4	14	14	14	16
576.0	4	5	6	7
575.6	0	0	1	1
575.2	0	0	0	0
Minimum	575.62	575.61	575.58	572.52
All Months				
576.8 LWD	91	96	101	120
576.4	38	38	39	47
576.0	16	17	18	21
575.6	4	5	6	8
575.2	0	0	0	0
Minimum	575.47	575.45	575.42	575.36

Table 33 - Monthly Mean Water Levels of Lake Erie, 1900-1976
Number of Occurrences Above Level Shown

Monthly Mean Level (Feet)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
573.0	16	11	3	0
572.8	27	18	11	0
572.6	37	29	14	0
572.4	55	39	26	5
572.2	78	63	37	12
572.0	108	89	58	16
Maximum	573.60	573.45	573.18	572.53

Table 34 - Monthly Mean Water Levels of Lake Erie, 1900-1976
Number of Occurrences Below Level Shown

Monthly Mean Level (Feet)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
April-November				
569.0	8	9	11	22
568.8	4	5	5	12
568.6 LWD	3	3	3	6
568.4	1	1	1	1
568.2	0	0	0	0
Minimum	568.32	568.30	568.28	568.24
All Months				
569.0	30	33	37	68
568.8	24	25	27	49
568.6 LWD	15	16	18	24
568.4	4	4	5	7
568.2	1	1	1	2
568.0	0	0	0	1
Minimum	568.09	568.07	568.02	567.84

River Board of Control to the International Joint Commission. These criteria and the tests of regulation plans by that Board related to the 1860-1954 period. For evaluation purposes in this study, as noted in Section 3.2, the data base period of record is 1900-1976, and the basis-of-comparison includes the current operating plan (Plan 1958-D) as designed for the period 1900-1960 and as actually operated thereafter. In the following paragraphs each criterion and supplementary requirement of regulation is stated, followed by a discussion with tables showing the degree to which each plan fulfills these requirements in comparison with the basis-of-comparison. It should be noted that under Category 1 of this study there is no attempt to modify Plan 1958-D to accommodate the increased inflow from limited regulation of Lake Erie.

Criterion (a). The regulated outflow from Lake Ontario from April 1 to December 15 shall be such as not to reduce the minimum level of Montreal Harbour below that which would have occurred in the past with the supplies to Lake Ontario since 1860 adjusted to a condition assuming a continuous diversion out of the Great Lakes basin of 3,100* cubic feet per second at Chicago and a continuous diversion into the Great Lakes basin annually of 5,000 cubic feet per second from the Albany River basin.

Lake St. Louis outflows are representative of the levels of Montreal Harbour. A comparison of the minimum monthly mean outflows from Lake St. Louis with basis-of-comparison data will indicate the degree to which the criterion would be satisfied. To assess the effect of regulation on low water levels of Montreal Harbour, it has been customary in the studies conducted by the International St. Lawrence River Board of Control to compare the frequency of occurrence of outflows from Lake St. Louis below 230,000 cfs.

Table 35 shows that the minimum outflow from Lake St. Louis under all three plans is almost the same as that which occurred under the basis-of-comparison. The table also shows a slight increase in low flows below 230,000 cfs under Plans 15S and 25N; however, at flows less than 225,000 cfs the frequency of occurrence under all three plans is practically the same as under the basis-of-comparison.

Criterion (b). The regulated winter outflows from Lake Ontario from December 15 to March 31 shall be as large as feasible and shall be maintained so that the difficulties of winter operation are minimized.

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*Changed to 3,200 cfs in this study.

Table 35 - Monthly Mean Outflows from Lake St. Louis Under Category 1 April 1 - December 15, 1900-1976; Number of Months Below Outflow Shown

Monthly Mean Level (Thousands in cfs)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
230	27-1/2	27-1/2	29	31-1/2
225	15	15	15	16
220	9-1/2	9-1/2	9-1/2	8-1/2
215	5	5	5	6
210	0	0	0	0
Minimum	212	212	212	211

NOTE: Half values indicate occurrences during the first half of December.

Table 36 shows that the minimum outflows under all three plans are the same as occurred under the basis-of-comparison and, thus, the criterion has been satisfied.

Criterion (c). The regulated outflow from Lake Ontario during the annual spring break-up in Montreal Harbour and in the river downstream shall not be greater than would have occurred assuming supplies of the past as adjusted.

In applying this criterion, consideration must be given to the ice breaking activities which take place each year in the St. Lawrence Ship Channel. Past records show that the annual breakup in Montreal Harbour generally has occurred during the first half of April. The ice breaking activities in recent years have tended to modify the application of this criterion, either by advancing the time of ice break-up into March or by minimizing the serious flooding which can result at the time of the breakup. Table 37 compares the results obtained under the various plans with the basis-of-comparison.

Table 37 shows that the maximum outflow from Lake Ontario under all three plans is the same as occurred under the basis-of-comparison. However, the table also shows that there is a slight increase in frequency of occurrence of flows above 250,000 cfs with each plan. Hence, this criterion would not be satisfied to the same degree as under the basis-of-comparison.

Criterion (d). The regulated outflow from Lake Ontario during the annual flood discharge from the Ottawa River shall not be greater than the discharge that would have occurred assuming supplies of the past as adjusted.

This criterion is included to protect the riparian interests on Lake St. Louis, in Montreal Harbour, and on the river downstream. Past records show that the maximum level of Lake St. Louis each year, influenced to a significant extent by the flood flow of the Ottawa River, has occurred about 60 percent of the time in the month of May, with the remainder of the seriously high conditions in April and June. Table 38 indicates the extent to which this criterion would be met by the various plans presented herein.

Table 38, which compares the outflows under the three plans during the critical periods with those of the basis-of-comparison, shows that the maximum outflows from Lake Ontario under all plans is the same. However, the table does show a slight reduction in the maximum outflow from Lake St. Louis under Plans 15S and 25N from that which occurred under the basis-of-comparison during June. In general, with reference to the frequency of occurrence of high flows from Lake St. Louis, the table shows a slight increase in outflows from 380,000 to 410,000 cfs, but above that point there would be very little change from the basis-of-comparison. From the table, it can be concluded that, in general, this criterion would be satisfied by the three plans to the same degree as the basis-of-comparison.

Table 36 - Winter Outflows from Lake Ontario Under Category 1, 1900-1976
(Thousands of Cubic Feet Per Second)

Period	Basis-of-Comparison			Plan 6L			Plan 15S			Plan 25N		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
December 15-31	279	188	226	282	188	226	280	188	227	280	188	226
January	250	185	217	250	185	217	250	185	217	250	185	216
February	285	182	228	285	182	229	285	182	229	285	182	228
March	300	179	234	300	179	234	300	179	235	300	179	234

Table 37 - Monthly Mean Outflows from Lake Ontario Under Category 1, March and First-Half April 1900-1976
Number of Occurrences Above Outflow Shown

Outflow (Thousands in cfs)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
March				
250	19	22	22	23
260	11	13	14	13
270	7	8	8	8
280	4	4	4	4
290	2	2	2	2
Maximum	300	300	300	300
First Half April				
250	28	28	30	30
260	17	17	21	20
270	11	11	14	14
280	6	8	9	9
290	5	6	6	6
Maximum	318	318	318	318

Table 38 - Monthly Mean Outflows from Lakes Ontario and St. Louis Under Category 1
April, May, and June 1900-1976
Number of Occurrences Above Outflow Shown

Outflow	Basis-of-Comparison			Plan 6L			Plan 15S			Plan 25N		
(Thousands cfs)	Apr	May	Jun	Apr	May	Jun	Apr	May	Jun	Apr	May	Jun
Lake Ontario												
260	22	31	30	24	31	30	26	31	31	25	29	33
270	12	24	27	12	24	27	16	25	28	17	25	27
280	9	15	22	10	15	22	10	17	22	10	18	22
290	6	10	13	6	11	13	7	11	16	8	11	17
300	4	5	8	4	5	7	4	7	8	4	8	9
310	1	2	3	1	2	3	1	2	3	1	2	3
Maximum	324	337	350	324	337	350	324	337	350	324	337	350
Lake St. Louis												
380	8	14	6	9	14	6	11	15	7	12	16	7
390	5	14	6	5	14	6	5	14	5	6	14	5
400	5	13	3	5	13	3	5	14	3	5	14	3
410	3	9	2	3	9	2	4	12	2	4	10	3
420	2	5	1	2	5	1	2	5	1	2	6	1
430	1	3	1	1	3	1	1	3	1	1	3	1
440	1	2	0	1	2	0	1	2	0	1	2	0
450	1	0	0	1	0	0	1	0	0	1	0	0
Maximum	452	448	439	452	448	438	452	448	436	451	448	432

Table 39 - Minimum Monthly Mean Outflows from Lake Ontario Under Category 1, 1900-1976 (TCFS)

Month	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
January	185	185	185	185
February	182	182	182	182
March	179	179	179	179
April	177	177	177	177
May	176	176	176	176
June	190	190	190	189
July	200	200	199	198
August	201	201	200	199
September	201	200	200	199
October	196	196	196	195
November	198	198	198	198
December	192	192	192	192

Criterion (e). Consistent with other requirements, the minimum regulated outflows from Lake Ontario shall be such as to secure the maximum dependable flow for power.

Table 39 shows that the minimum flows under all three plans are essentially the same as occurred under the basis-of-comparison. Hence, this criterion would be satisfied to the same degree as under the basis-of-comparison.

Criterion (f). Consistent with other requirements, the maximum regulated outflow from Lake Ontario shall be maintained as low as possible to reduce channel excavation to a minimum.

The most important consideration in connection with Criterion (f) is that the plans should not produce more critical conditions than those under the current operating plan. Figure 27 shows the open-water envelope of water levels versus outflows for Plan 1958-D and the plans presented herein. Consideration of the points outside the envelope of Plan 1958-D indicates that conditions under the plans require higher outflows at the same Lake Ontario levels above 244.0 feet.

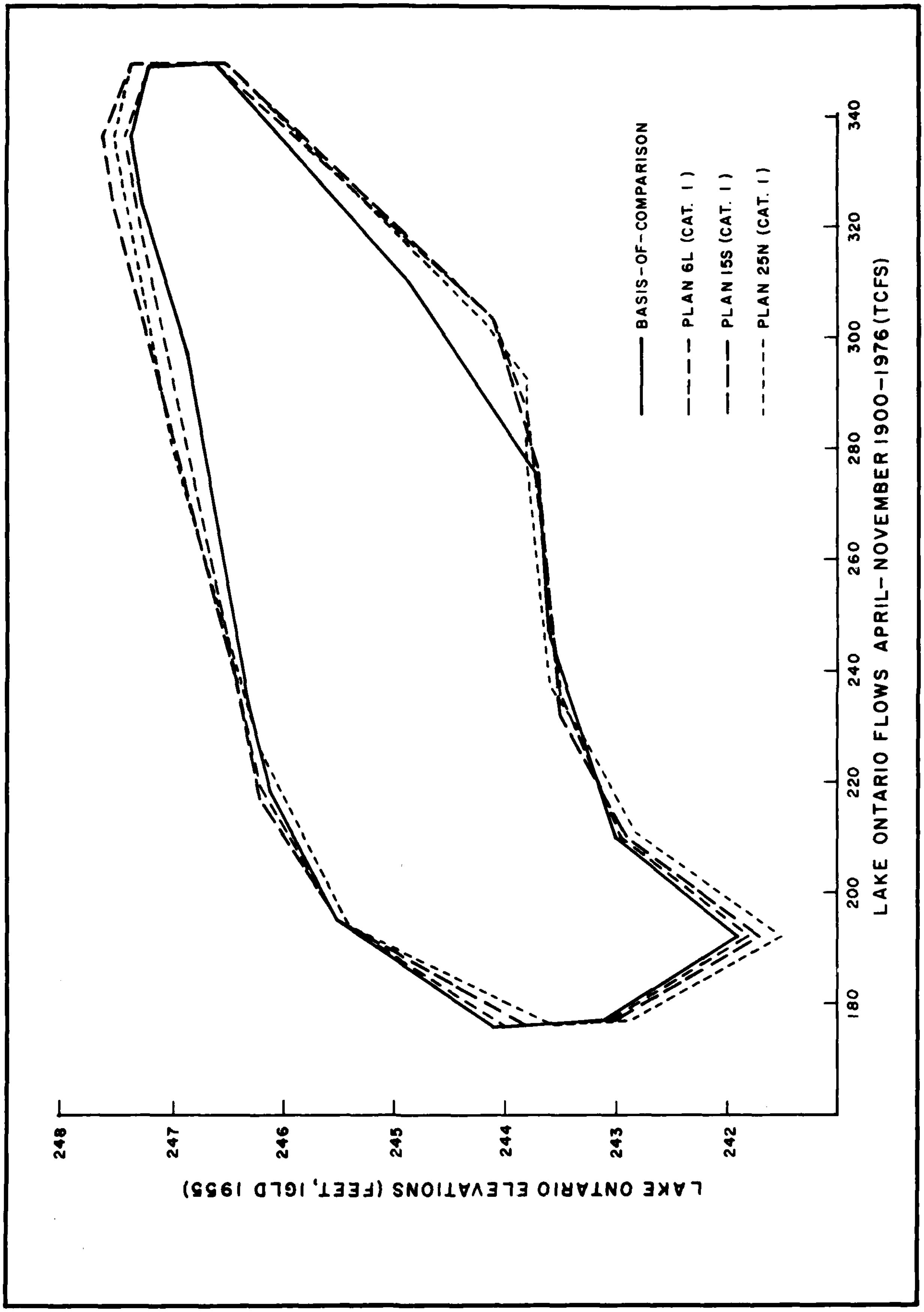
Criterion (g). Consistent with other requirements, the levels of Lake Ontario shall be regulated for the benefit of property owners on the shores of Lake Ontario in the United States and Canada so as to reduce the extremes of stage which have been experienced.

Table 40 - Lake Ontario Water Levels
Under Category 1

	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
Mean	244.61	244.64	244.65	244.63
Maximum	247.37	247.39	247.56	247.50
Minimum	241.81	241.74	241.59	241.38
Range	5.56	5.65	5.97	6.12

Table 40 shows a comparison of the lake level conditions resulting under the three plans with those of the basis-of-comparison. The table shows that as the outflow of Lake Erie increases the range of extreme levels also increases. In general, the criterion would not be satisfied to the same degree as the basis-of-comparison. However, it should be noted that there was no attempt to do so. Modifications to Plan 1958-D to accommodate the increased inflow from Lake Erie were accomplished under Categories 2 and 3.

Criterion (h). The regulated monthly mean level of Lake Ontario shall not exceed elevation 246.77 with the supplies of the past as adjusted.



CATEGORY I ENVELOPE OF LAKE ONTARIO WATER LEVELS
VS. OUTFLOWS, OPEN WATER PERIOD

Table 41 is consistent with the finding under Criterion (g). As the outflow from Lake Erie is increased the exceedence of 246.77 feet is increased. However, as stated under Criterion (g), there has been no attempt under Category 1 plans to offset this increase.

Criterion (i). Under regulation, the frequency of occurrences of monthly mean elevations of approximately 245.77 feet and higher on Lake Ontario shall be less than would have occurred in the past with the supplies of the past as adjusted and with present channel conditions in the Galop Rapids reach of the International Rapids Section of the St. Lawrence River.

Table 42 reflects the same condition described under Criterion (g) and (h).

Criterion (j). The regulated level of Lake Ontario on April 1 shall not be lower than elevation 242.77. The regulated mean level of the lake from April 1 to November 30 shall be maintained at or above elevation 242.77.

Table 43 shows a general lowering of the minimum April 1 elevation and the minimum monthly mean level for the period April 1 through November 30 under all three plans. Hence, the criterion would not be satisfied to the same degree. (See note Criterion (g)).

Criterion (k). In the event that future supplies occur in excess of the supplies of the past as adjusted, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream. In the event of future supplies less than the supplies of the past as adjusted, the works in the International Rapids Section shall be operated to provide all possible relief to navigation and power interests.

All plans were developed using the supplies of the past as adjusted, and this criterion refers to magnitudes and sequences of supplies in the future that may be more critical than those of the past. Since this condition refers to future conditions, it cannot be evaluated.

Table 41 - Monthly Mean Levels of Lake Ontario Under Category 1 1900-1976
Number of Occurrences Above Elevation 246.77

Plan	Occurrences
Basis-of-Comparison	8
Plan 6L	9
Plan 15S	10
Plan 25N	14

Table 42 - Monthly Mean Levels of Lake Ontario Under Category 1, 1900-1976
Number of Occurrences Equal to or Above Elevation 245.77

Plan	Occurrences
Basis-of-Comparison	100
Plan 6L	103
Plan 15S	112
Plan 25N	114

Table 43 - Lake Ontario Water Levels Under Category 1
Minimum April 1 and Minimum April-November

Plan	Minimum April 1	Minimum Monthly Mean Apr-Nov
Basis-of-Comparison	242.62	242.25
Plan 6L	242.56	242.19
Plan 15S	242.46	242.04
Plan 25N	242.24	241.89

Lake St. Louis Low Water Levels. One supplementary requirement of regulation relates to Lake St. Louis low water levels and states that "The project works shall be operated in such a manner as to provide no less protection for navigation and riparian interests downstream than would have occurred under preproject conditions with the supplies of the past as adjusted, as defined in Criterion (a) herein."

Table 44 shows that the minimum level under all three plans would be lowered slightly below that which occurred under the basis-of-comparison. The frequency of the occurrence of these low levels under Plans 15S and 25N has also been increased. However, as noted above, no attempt has been made to correct this condition.

6.1.3 Category 2 and 3 Plans.

As noted previously, Categories 2 and 3 consist of modification to the Lake Ontario portion of the Category 1 plans to accommodate Lake Erie regulation. Category 2 consists of modifying Plan 1958-D to such an extent as to satisfy the previously stated Lake Ontario criteria to the same degree as occurred under actual operation.

Category 3 consists of modifying the St. Lawrence River channels and Plan 1958-D to satisfy the criteria as stated and accommodate Lake Erie regulation. As noted in Section 4.6, as part of the Category 3 exercise, an adjusted basis-of-comparison was developed to separate the impacts attributed to limited regulation of Lake Erie from those impacts caused by the extreme supplies of the 1960's and 1970's. Table 45 is a hydrologic summary of Categories 2 and 3 plans. Rather than restate the criteria (given above) in their entirety, they have been paraphrased in the following section.

Criterion (a) - Mean Outflows from Lake St. Louis.

Table 46 shows the results obtained under Category 2 and 3 modifications to Regulation Plan 1958-D. The table shows that the minimum flow from Lake St. Louis under Category 2 is essentially the same as the basis-of-comparison, with an increase in the frequency of occurrence of low St. Louis outflows. Comparison under Category 3 with the adjusted basis-of-comparison produces similar results, i.e., same minimum flows with an increase in frequency of low flows.

Criterion (b) - Winter Outflows from Lake Ontario.

Table 47 shows that regulation of Lake Erie provides an improvement in the minimum flow situation on Lake Ontario in both categories. A comparison of regulation plans in Categories 2 and 3 to their respective bases-of-comparison shows that the maximum winter flows would generally be reduced. Comparison of the basis-of-comparison and the adjusted basis-of-comparison shows that the latter generally provides higher minimum outflows and lower maximum outflows.

Criterion (c) - Outflow from Lake Ontario During Spring Breakup in Montreal Harbour.

Table 44 - Lake St. Louis Low Water Levels Under Category 1
June, July, August, September 1900-1976
(Number of Months Below Values Shown)

Stage	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
67.0	77	77	86	87
66.5	36	36	38	39
66.0	8	7	7	7
65.5	0	0	0	2
Minimum	65.55	65.53	65.53	65.48

Table 45 - Summary of Hydrologic Evaluation of Lake Ontario for Categories 2 and 3

Category 2, Monthly Mean Levels of Lake Ontario, 1900-1976

Water Levels (ft.)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
Mean	244.61	244.66	244.69	244.71
Maximum	247.37	247.34	247.42	247.45
Minimum	241.81	242.04	242.12	242.21
Range	5.56	5.30	5.30	5.24

Category 3, Monthly Mean Levels of Lake Ontario, 1900-1976

Water Levels (ft.)	Basis-of-Comparison	Adjusted Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
Mean	244.61	244.63	244.64	244.65	244.67
Maximum	247.37	246.77	246.79	246.84	246.83
Minimum	241.81	242.38	242.32	242.34	242.47
Range	5.56	4.39	4.47	4.50	4.36

Table 46 - Monthly Mean Outflows from Lake St. Louis
Under Categories 2 and 3
April 1-December 15, 1900-1976
Number of Months Below Outflow Shown

Outflow (Thousands of cfs)	Basis-of-Comparison	Category 2		
		Plan 6L	Plan 15S	Plan 25N
230	27-1/2	29-1/2	31	35-1/2
225	15	14	15-1/2	17-1/2
220	9-1/2	6	6	11-1/2
215	5	2	2	2
210	0	0	0	0
Minimum	212	213	212	211

Outflow (Thousands of cfs)	Basis-of-Comparison	Adjusted Basis-of-Comparison	Category 3		
			Plan 6L	Plan 15S	Plan 25N
230	27-1/2	30	30	31-1/2	37-1/2
225	15	15-1/2	15-1/2	16-1/2	18
220	9-1/2	8-1/2	8-1/2	11-1/2	11-1/2
215	5	2	2	2	2
210	0	0	0	0	0
Minimum	212	212	212	212	211

NOTE: Half values indicate occurrences during the first half of December

Table 47 - Winter Outflows from Lake Ontario Under Categories 2 and 3, 1900-1976
(Thousands of Cubic Feet Per Second)

Period	Basis-of-Comparison			Category 2								
				Plan 6L			Plan 15S			Plan 25N		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
December 15-31	279	188	226	296	205	231	296	204	231	296	202	230
January	250	185	217	235	205	218	235	204	218	235	202	217
February	285	182	228	280	202	229	280	200	229	280	200	229
March	300	179	234	297	195	233	297	196	234	297	195	232

Period	Basis-of-Comparison			Adjusted Basis-of-Comparison			Category 3								
							Plan 6L			Plan 15S			Plan 25N		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
December 15-31	279	188	226	304	203	229	304	203	229	309	202	230	304	200	228
January	250	185	217	234	203	214	234	203	215	234	202	215	235	200	213
February	285	182	228	280	200	230	280	200	230	280	200	231	280	200	230
March	300	179	234	294	196	233	295	196	234	296	195	235	295	195	233

Table 48 shows, under Categories 2 and 3, there would be a general reduction in the maximum flows during March, when compared to their respective bases-of-comparison. April produces the reverse condition with the plans being higher than the bases. However, the table does show a small general increase in the frequency of high outflows (above 250,000 cfs). The adjusted basis-of-comparison also increases the frequency of high outflows for March and April, when compared to the basis-of-comparison.

Overall, it would appear that the three plans which include Lake Erie regulation do not satisfy the criterion as well as current conditions (without Lake Erie regulated).

Criterion (d) - Annual Flood Discharge Ottawa River.

The annual flood discharge is evaluated by comparison of flows out of Lake Ontario and Lake St. Louis, during the months of April, May, and June. Table 49 provides this comparison. The table shows that under Category 2 the maximum outflows from Lake Ontario are less than that under the basis-of-comparison. However, for Lake St. Louis outflow, the maximum outflow is somewhat higher, and the frequency of flows above 380,000 cfs is approximately the same as occurred under the basis-of-comparison. Under Category 3, the maximum outflows, as well as the frequency of occurrence of high outflows, from Lake Ontario are the same under Plan 6L as under the adjusted basis-of-comparison. Plans 15S and 25N produce higher maximum outflows and a higher frequency of occurrence of high flows than the adjusted basis-of-comparison. On Lake St. Louis, all three plans produce higher maximum outflows and frequency of occurrence of high flows than the basis-of-comparison. Comparison of the basis-of-comparison with the adjusted base shows higher maximum and higher frequency of occurrence of high flows under the latter. However, it should be noted that under Category 3, there would be channel enlargements in both the International and Canadian Reaches of the St. Lawrence River. These enlargements would offset the effect of these high outflows (west of Montreal in the Canadian Reach) and make the level condition no worse than occurred under the basis-of-comparison. The increase in the frequency of high St. Lawrence outflow would have an adverse effect downstream. However, consideration of remedial measures downstream of Lake St. Louis was beyond the scope of this study.

Criterion (e) - Minimum Outflow from Lake Ontario.

Table 50 compares the minimum outflows under each regulation plan for both categories. The table shows that there would be generally higher minimum outflows under Category 2. For Category 3, the adjusted basis-of-comparison would also provide higher minimum flows. Compared to the adjusted basis-of-comparison, all three plans would provide slightly lower minimum flows in the months of October through December.

Criterion (f) - Maintain the Maximum Outflows As Low As Possible So As to Reduce Channel Excavation.

The most important consideration in connection with Criterion (f) is that the plans should not produce more critical conditions than those which

Table 48 - Monthly Mean Outflows from Lake Ontario
Under Categories 2 and 3,
March and First Half April 1900-1976,
Number of Occurrences Above Outflow Shown

Category 2, March

Outflow (Thousands in cfs)	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
250	19	20	22	23
260	11	8	11	11
270	7	7	7	8
280	4	4	4	3
290	2	1	2	1
Maximum	300	297	297	297

Category 2, First Half April

250	28	28	30	29
260	17	15	20	21
270	11	11	13	14
280	6	8	9	9
290	5	6	6	6
Maximum	318	318	320	319

Table 48 (Cont'd) - Monthly Mean Outflows from Lake Ontario
Under Categories 2 and 3,
March and First Half April 1900-1976,
Number of Occurrences Above Outflow Shown

Category 3, March

Outflow (Thousands in cfs)	Basis-of-Comparison	Adjusted Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
250	19	23	23	26	25
260	11	11	13	15	16
270	7	7	7	8	8
280	4	4	4	6	4
290	2	1	1	1	1
Maximum	300	294	295	297	295

Category 3, First Half April

Outflow (Thousands in cfs)	Basis-of-Comparison	Adjusted Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
250	28	29	30	33	30
260	17	19	20	23	25
270	11	12	13	16	15
280	6	10	11	12	12
290	5	9	9	9	9
Maximum	318	331	332	336	332

Table 49 - Monthly Mean Outflows from Lakes Ontario and St. Louis Under Categories 2 and 3, April, May, and June 1900-1976 Number of Occurrences Above Outflow Shown

Category 2

Outflows (TCFS)	Basis-of-Comparison			Plan 6L			Plan 15S			Plan 25N		
	April	May	June	April	May	June	April	May	June	April	May	June
Lake Ontario												
260	22	31	30	22	31	30	28	31	30	26	30	32
270	12	24	27	13	24	27	17	26	27	16	26	27
280	9	15	22	11	15	21	10	17	21	11	19	22
290	6	10	13	6	11	13	8	12	15	9	11	17
300	4	5	8	4	6	9	5	7	9	5	8	9
310	1	2	3	2	3	4	3	3	4	1	3	6
Maximum	324	337	350	321	324	325	322	325	326	322	325	326
Lake St. Louis												
380	8	14	6	10	14	6	12	18	7	11	18	8
390	5	14	6	5	14	4	5	14	3	6	14	3
400	5	13	3	5	11	3	5	13	3	5	13	3
410	3	9	2	3	8	1	4	9	1	4	9	2
420	2	5	1	2	5	1	2	5	1	2	5	1
430	1	3	1	1	3	1	1	3	1	1	3	1
440	1	2	0	1	2	0	1	2	0	1	1	0
450	1	0	0	1	1	0	1	1	0	1	1	0
Maximum	452	448	439	459	458	438	458	460	436	454	459	432

Table 49 (Cont'd) - Monthly Mean Outflows from Lakes Ontario and St. Louis
Under Categories 2 and 3
April, May, and June 1900-1976
Number of Occurrences Above Outflow Shown

Category 3

Outflows (TCFS)	Basis-of-Comparison			Adjusted Basis-of-Comparison			Plan 6L			Plan 15S			Plan 25N		
	April	May	June	April	May	June	April	May	June	April	May	June	April	May	June
260	22	31	30	23	31	30	23	31	30	29	31	30	25	29	32
270	12	24	27	15	24	27	15	23	26	18	26	26	15	26	25
280	9	15	22	12	17	23	11	16	20	13	18	21	12	20	21
290	6	10	13	9	13	14	9	12	14	10	12	15	9	14	18
300	4	5	8	6	7	9	7	7	8	9	7	11	8	8	12
310	1	2	3	4	4	6	4	4	6	5	6	6	5	6	6
Maximum	324	337	350	332	334	334	333	334	334	338	340	337	333	334	334
Lake St. Louis															
380	8	14	6	10	15	10	11	15	9	12	18	10	12	18	10
390	5	14	6	6	14	5	9	14	5	10	14	4	11	14	6
400	5	13	3	5	13	3	5	13	3	5	13	3	5	13	4
410	3	9	2	5	9	3	5	9	3	5	10	3	5	10	3
420	2	5	1	4	7	1	4	6	1	5	6	1	4	7	2
430	1	3	1	2	5	1	2	5	1	2	6	1	3	6	1
440	1	2	0	1	3	1	1	3	1	2	3	1	2	2	1
450	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0
Maximum	452	448	439	473	468	453	473	468	452	473	473	451	469	469	446

Table 50 - Minimum Monthly Mean Outflows from Lake Ontario Under Categories 2 and 3, 1900-1976. (TCFS)

Category 2

Outflow	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
January	185	205	204	202
February	182	202	200	200
March	179	195	196	195
April	177	188	188	188
May	176	188	188	188
June	190	194	193	192
July	200	200	199	198
August	201	201	200	199
September	201	202	202	202
October	196	205	204	202
November	198	205	204	202
December	192	205	204	202

Table 50 (Cont'd) - Minimum Monthly Mean Outflows from Lake Ontario Under Categories 2 and 3 1900-1976 (TCFS)

Category 3

Outflow	Basis-of-Comparison	Adjusted Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
January	185	203	203	202	200
February	182	200	200	200	200
March	179	196	196	195	195
April	177	188	188	188	188
May	176	188	188	188	188
June	190	193	193	193	192
July	200	200	200	199	198
August	201	201	201	200	199
September	201	202	202	202	200
October	196	203	203	202	200
November	198	203	203	202	200
December	192	203	203	202	200

occur under the current operating plan. It should be noted that the current operating rule does not satisfy the criteria over the 1900-1976 test period. Hence, to evaluate this criterion and to determine that portion of the channel increase which can be attributed to Lake Erie regulation, as noted it was first necessary to adjust the basis-of-comparison so that it satisfied the criteria. Figure 28 shows the open-water envelope of water levels versus outflow for the basis-of-comparison and the three plans under Category 2. Figure 29 shows similar envelopes for Category 3 regulation plans as well as the adjusted basis-of-comparison. This figure shows that if the necessary channel enlargements were made as required by the adjusted basis-of-comparison, these modifications would be adequate to handle Plan 6L. Plans 15S and 25N, however, would require further minor channel enlargements. Section 5.3.1 of the main report and Appendix B - Regulatory Works, provide more detailed information on channel excavation requirements.

Criterion (g) - Monthly Mean Lake Ontario Levels.

Table 45 shows a comparison of the maximum, mean, and minimum levels under all plans for Categories 2 and 3. The table shows that generally, the maximum, minimum, and mean stages would be slightly increased under Category 2. However, the range of stage would be reduced. Under Category 3, the adjusted basis-of-comparison maximum stage would be reduced to the maximum permissible stage of 246.77 feet. The three lake plans, however, would increase the maximum stages slightly, but this increase would be less than 0.1 foot.

Criterion (h) - Monthly Occurrence Above 246.77.

As shown in Table 51, there is an increase in the number of occurrences above elevation 246.77 under Category 2. The adjusted basis-of-comparison would not provide any stages higher than 246.77 feet. However, Plans 6L, 15S, and 25N would provide a few occurrences above 246.77 feet.

Criterion (i) - Monthly Occurrence Above 245.77 feet.

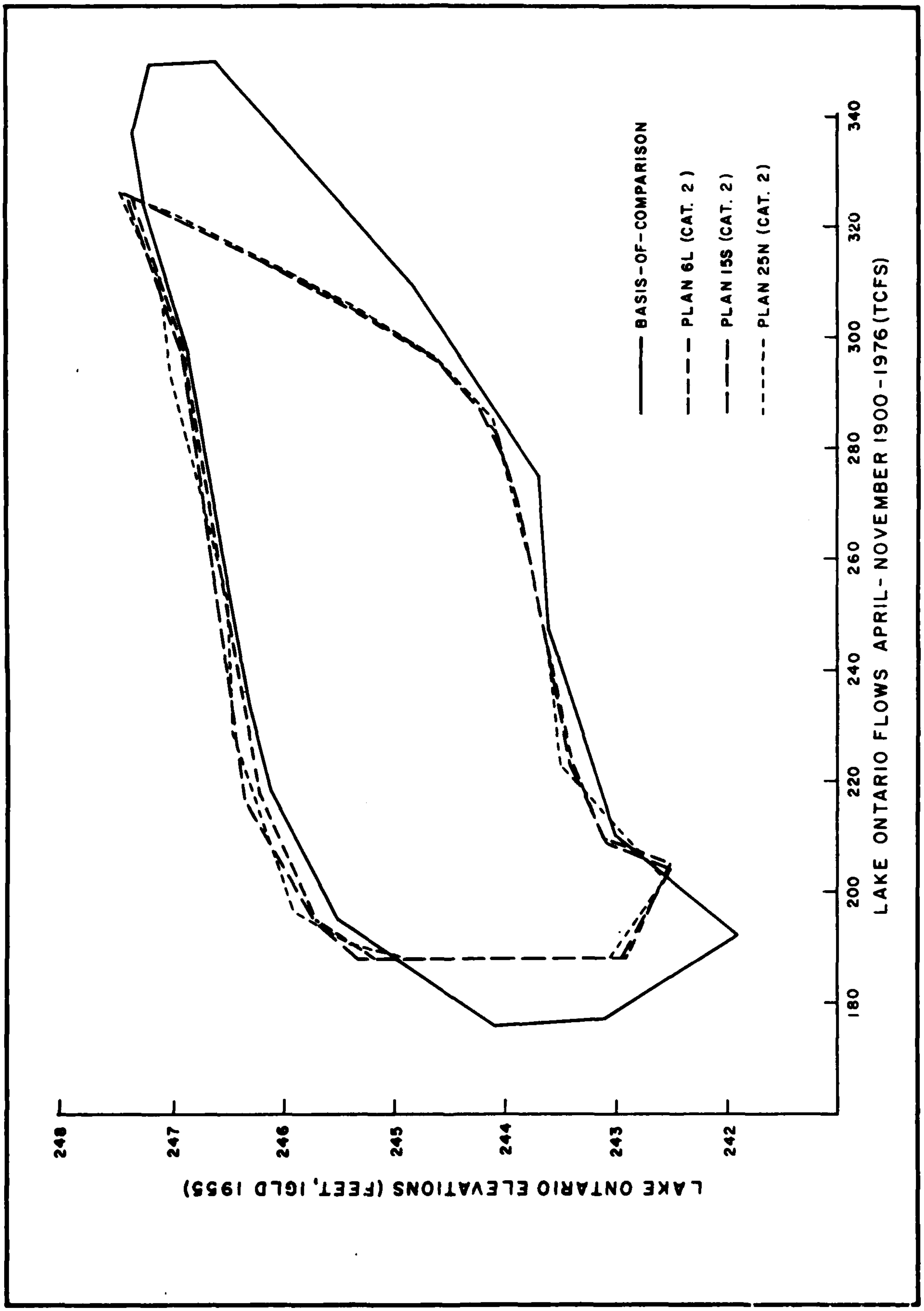
Table 52 compares the frequency of occurrences of levels above 245.77 feet. The table shows that Category 2 does not satisfy the criterion to the same degree as under the current operating rule. Under Category 3, the number of occurrences above elevation 245.77 for the adjusted basis-of-comparison would be reduced to 86. For Plan 6L, 15S, and 25N, they would be increased slightly.

Criterion (j) - Minimum Level During the Navigation Season.

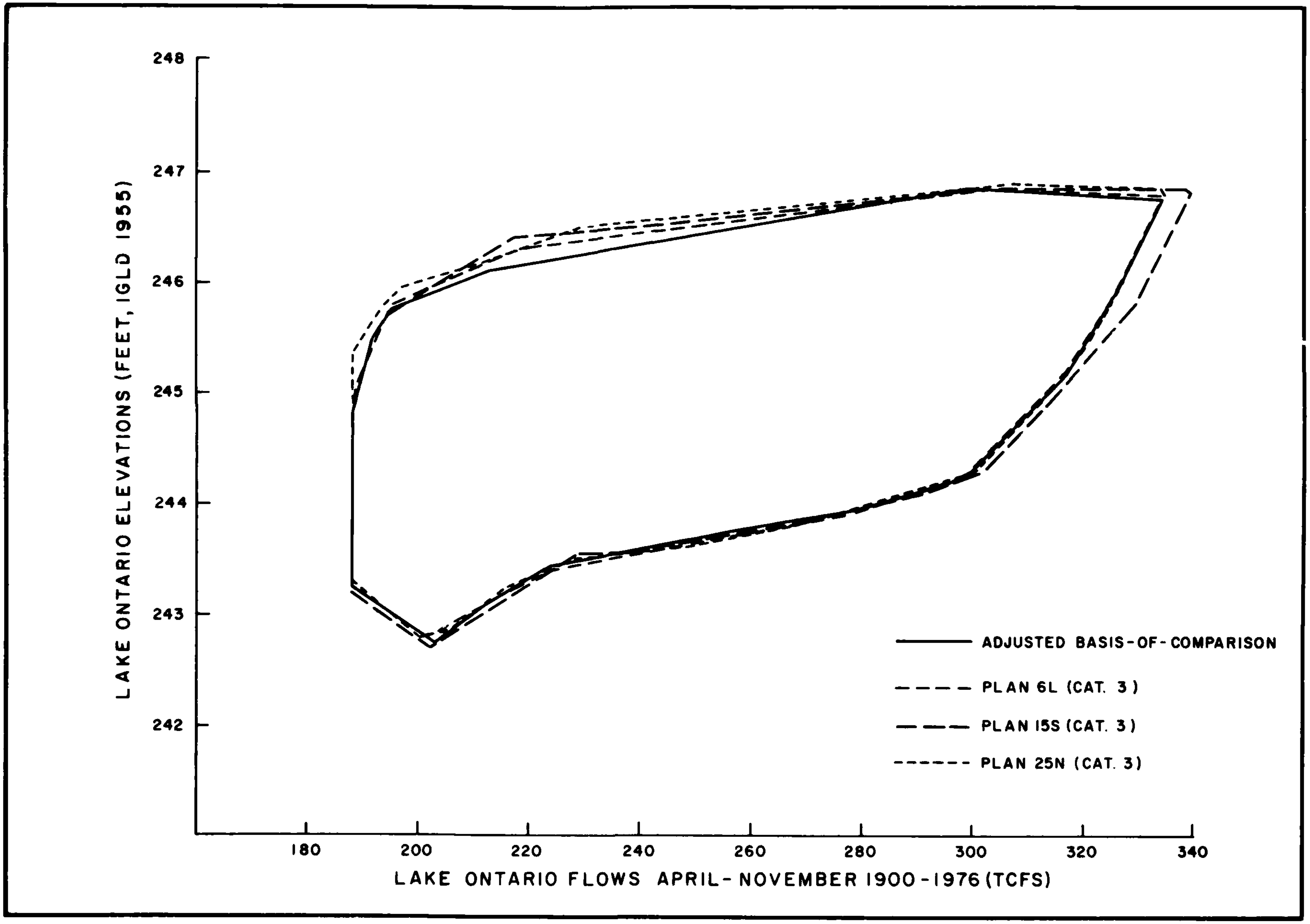
Table 53 shows that under Category 2, the minimum monthly mean levels for all plans during the period April to November would be higher than that under the basis-of-comparison. In Category 3, the adjusted basis-of-comparison and all three plans provide higher minimum April 1 levels and increased minimum monthly mean levels for April through November.

Criterion (k) - See discussion under Category 1.

Lake St. Louis - Supplementary Requirement Related to Low Levels.



CATEGORY 2 ENVELOPE OF LAKE ONTARIO WATER LEVELS VS. OUTFLOWS, OPEN WATER PERIOD



CATEGORY 3 ENVELOPE OF LAKE ONTARIO WATER LEVELS
VS. OUTFLOWS, OPEN WATER PERIOD

Table 51 - Monthly Mean Levels of Lake Ontario Under Categories 2 and 3, 1900-1976, Number of Occurrences Above Elevation 246.77

Plan	Occurrences
Category 2	
Basis-of-Comparison	8
Plan 6L	11
Plan 15S	13
Plan 25N	17
Category 3	
Basis-of-Comparison	8
Adjusted Basis-of-Comparison	0
Plan 6L	1
Plan 15S	3
Plan 25N	4

Table 52 - Monthly Mean Levels of Lake Ontario Under Categories 2, and 3 1900-1976, Number of Ocurrences Equal to Or Above Elevation 245.77

Plan	Occurrences
Category 2	
Basis-of-Comparison	100
Plan 6L	104
Plan 15S	110
Plan 25N	121
Category 3	
Basis-of-Comparison	100
Adjusted Basis-of-Comparison	86
Plan 6L	88
Plan 15S	90
Plan 25N	92

Table 53 - Lake Ontario Water Levels Under Categories 2 and 3, Minimum April 1 and Minimum April-November

Category 2

Plan	Minimum April 1	Minimum Monthly Mean April-November
Basis-of-Comparison	242.62	242.25
Plan 6L	242.48	242.89
Plan 15S	242.56	242.97
Plan 25N	242.63	243.04

Category 3

Plan	Minimum April 1	Minimum Monthly Mean April-November
Basis-of-Comparison	242.62	242.25
Adjusted Basis-of-Comparison	242.82	243.22
Plan 6L	242.76	243.16
Plan 15S	242.80	243.19
Plan 25N	242.67	243.24

Table 54 shows that the impact on the minimum level under Category 2 would be slight. However, there would be a slight increase in the frequency and occurrence of low levels. Under Category 3 plans, there would be very little change in the minimum level from that which occurred under the adjusted basis-of-comparison. There would be, however, a slight increase in the frequency of occurrence of low levels.

Criterion (a), (c), and (d) relate to outflows from Lakes Ontario and St. Louis. To measure the full impact over the entire period and range of flows, Figures 30 and 31 have been prepared. These figures show that under Category 3, the frequency of occurrence and magnitude of outflows would not be affected greatly by limited regulation of Lake Erie when compared to the adjusted basis-of-comparison.

Table 54 - Lake St. Louis Low Water Levels 1/ Under Categories 2 and 3, June, July, August, September, 1900-1976 Numbers of Months Below Value Shown

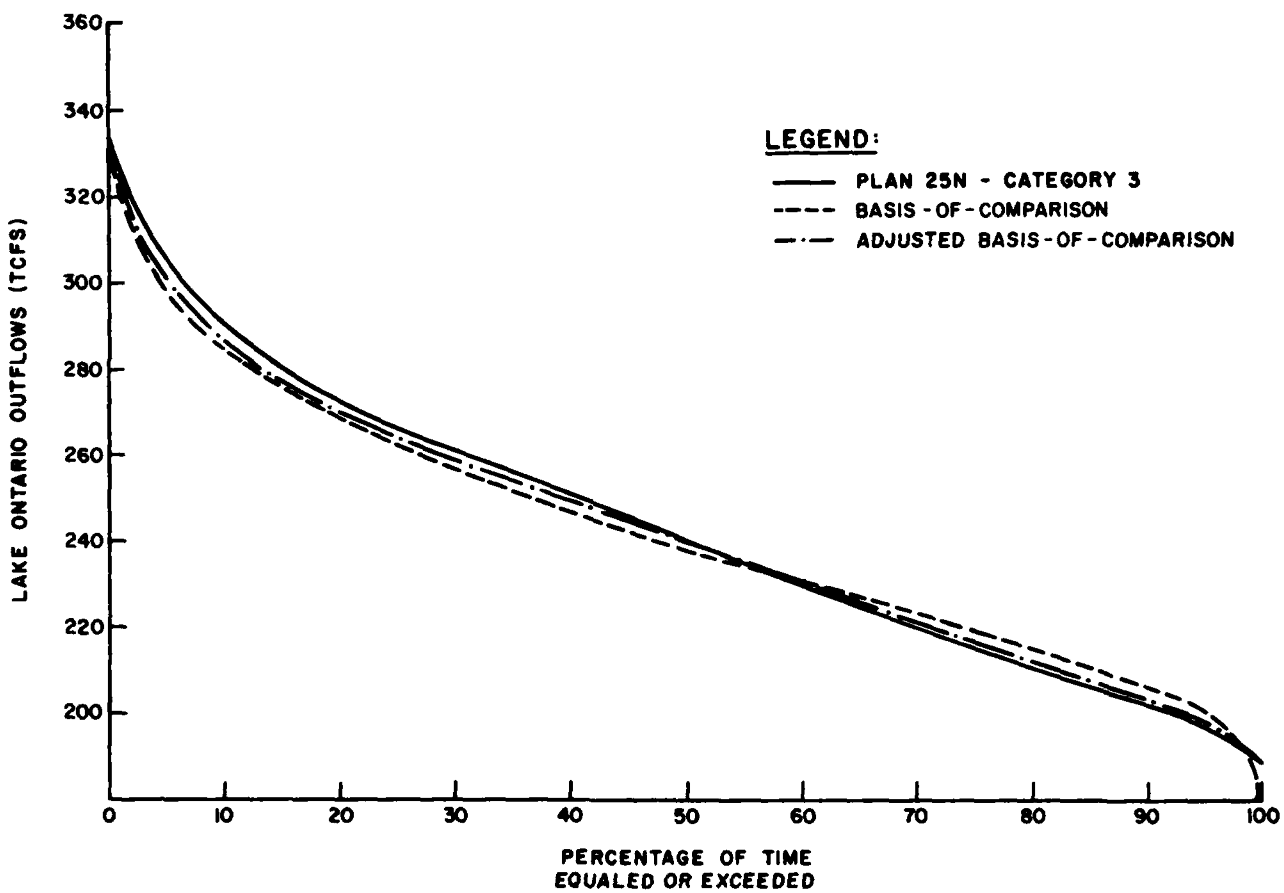
Category 2

Stage	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
67.0	77	73	81	85
66.5	36	36	37	39
66.0	8	6	7	8
65.5	0	0	0	1
65.0	0	0	0	0
Minimum	65.55	65.56	65.53	65.48

Category 3

Stage	Basis-of-Comparison	Adjusted Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
67.0	77	74	74	82	86
66.5	36	36	37	37	32
66.0	8	8	7	7	8
65.5	0	0	0	0	1
65.0	0	0	0	0	0
Minimum	65.55	65.55	65.55	65.53	65.48

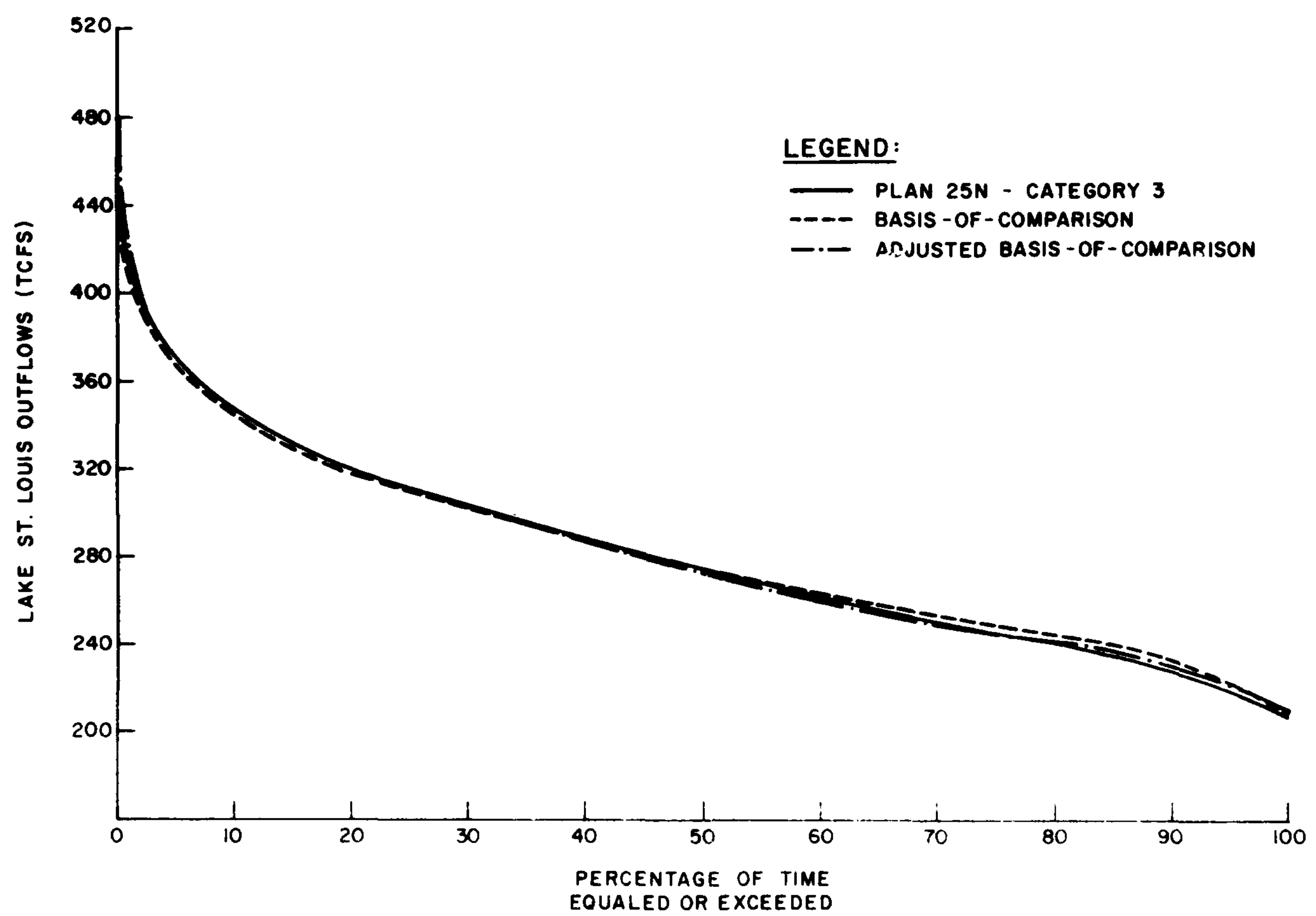
1/ At Lock 5, Lachine



LAKE ONTARIO MONTHLY MEAN DURATION CURVES

FIGURE 30

FIGURE 30



LAKE ST. LOUIS MONTHLY MEAN DURATION CURVES

6.1.4 Summary

The regulation plans evaluated herein were developed, employing the hydrologic data for the period 1900-1976, with the intent of reducing the high levels of Lake Erie as required by the Reference from the Governments. Table 55 provides a general synopsis of the degree to which the regulation plans meet the criteria outlined above. On the table, the following rating has been employed as a guide to describe the relative performance of each plan:

1. indicates that the criterion would be considered satisfied;

2. indicates that the criterion would be considered satisfied and improvement has also been shown over the basis-of-comparison or adjusted basis-of-comparison;

3. indicates that the criterion would not be considered satisfied; and

4. indicates that the criterion would not be considered satisfied, but improves upon the basis-of-comparison or adjusted basis-of-comparison.

The table shows that on Lakes Superior, Michigan-Huron, and Erie those criteria related to high lake levels would be satisfied and the frequency of occurrence of those levels would be reduced. However, because of the time lag in the system, the lowering of the high levels on those lakes would also impact on the lower levels. In general, on those lakes the summary shows that the intent of regulation under the Reference would be met.

On Lake Ontario, the summary shows that under Category 1, the placing of additional water on that lake would have a detrimental impact. However, the table also shows that when modifications to the regulation plan on that lake are instituted (Categories 2 and 3) the detrimental impact would be offset and general improvement over current regulation would be effected.

6.1.5 Effects of Increased Great Lakes Consumptive Uses on Lake Erie Regulation Plans

The term "consumptive use" refers to that portion of the water withdrawn or withheld from the Great Lakes and not returned. For the purposes of this study, the diversion of water from Lake Michigan at Chicago is excepted from this definition. In a sense, water consumption cannot be totally quantified when applied to a basin as large as that of the Great Lakes. Water lost at a particular site by evaporation may reappear within a relatively short distance as rain, and not be lost at all. However, the principle has been adopted that water consumed at any point in the basin is considered lost to the system. Consumptive uses include municipal, manufacturing, irrigation, rural-domestic, rural-stock, mining, and power generation activities.

The rate of consumptive uses of water within the Great Lakes Basin is not constant from year to year. Estimates of future uses throughout the basin were made in a study conducted by the International Great Lakes Diversions and Consumptive Uses Study Board. It is estimated that consumptive uses will increase considerably in the future.

Table 55 - Relative Hydrologic Performance of Regulation Plans

	Plan 6L	Plan 15S	Plan 25N
Lake Superior			
Criterion (a)	3	3	3
Criterion (b)	2	2	2
Criterion (c)	1	1	1
Criterion (d)	1	1	2
Criterion (e)	1	2	2
Lakes Michigan-Huron			
Criterion (a)	2	2	2
Criterion (b)	3	3	3
Lake Erie			
Criterion (a)	2	2	2
Criterion (b)	3	3	3
Lake Ontario - Category 1, compared to the basis-of-comparison			
Criterion (a)	1	1	1
Criterion (b)	1	1	1
Criterion (c)	3	3	3
Criterion (d)	1	1	1
Criterion (e)	1	1	1
Criterion (f)	1	1	1
Criterion (g)	3	3	3
Criterion (h)	3	3	3
Criterion (i)	3	3	3
Criterion (j)	3	3	3

Table 55 (Cont'd) - Relative Hydrologic Performance of Regulation Plans

	Plan 6L	Plan 15S	Plan 25N
Criterion (k)	N/A	N/A	N/A
(supp)	1	3	3
Lake Ontario - Category 2, compared to the basis-of-comparison			
Criterion (a)	1	1	1
Criterion (b)	2	2	2
Criterion (c)	3	3	3
Criterion (d)	1	1	1
Criterion (e)	2	2	2
Criterion (f)	2	2	2
Criterion (g)	2	2	2
Criterion (h)	1	1	1
Criterion (i)	3	3	3
Criterion (j)			
1 Apr	3	3	4
Apr-Nov	2	2	2
Criterion (k)	N/A	N/A	N/A
(supp)	1	1	1
Lake Ontario - Category 3, compared to the adjusted basis-of-comparison			
Criterion (a)	1	3	3
Criterion (b)	1	1	1
Criterion (c)	1	1	1
Criterion (d)	1	1	1
Criterion (e)	1	1	1

Table 55 (Cont'd) - Relative Hydrologic Performance of Regulation Plans

	Plan 6L	Plan 15S	Plan 25N
Criterion (f)	1	1	1
Criterion (g)	1	3	3
Criterion (h)	1	1	1
Criterion (i)	3	3	3
Criterion (j)			
1 Apr	1	1	3
Apr-Nov	1	1	2
Criterion (k)	N/A	N/A	N/A
(supp)	1	1	3

Lake Ontario - Adjusted Basis-of-Comparison
Compared to Basis-of-Comparison

Criterion (a)	1
Criterion (b)	1
Criterion (c)	3
Criterion (d)	3
Criterion (e)	2
Criterion (f)	1
Criterion (g)	2
Criterion (h)	2
Criterion (i)	2
Criterion (j)	
1 April	2
April-November	2
Criterion (k)	N/A
(supp)	2

Key: 1 - the criterion would be satisfied;
2 - the criterion would be satisfied and improvement has also been shown over the basis-of-comparison
3 - the criterion would not be satisfied;
4 - the criterion would not be satisfied, but improves upon the basis-of-comparison or adjusted basis-of-comparison
N/A - this criterion cannot be evaluated.

Consumptive uses of water, in effect, reduce the water supply to a lake and, in turn, affect the water levels of that lake and all lakes downstream. Since Lake Ontario is artificially regulated within given stage limits, consumptive uses have no appreciable effects on the levels of that lake. However, in order to operate within these limits with a reduced water supply, an average reduction in the outflow of Lake Ontario equal to the accumulated consumptive uses of water above its outlet would be required. The present regulation plan for Lake Ontario (Plan 1958-D) was developed and tested using the historical supplies for the period 1860-1954. With increasing consumptive uses, it is anticipated that Plan 1958-D would not be able to cope with the resulting extreme low supplies. Hence, Plan 1958-D would need to be reassessed at some future time.

Consumptive uses would also have an impact on the upper lakes (Lakes Superior and Michigan-Huron). Due to the operational nature of Plan 1977, it is estimated that the long-term mean water levels on these lakes would be reduced. Plans for the limited regulation of Lake Erie would also be affected. With decreasing supplies to the upper lakes, the index employed as a trigger to increase the outflow of Lake Erie would not be used as often. Supplies to Lake Erie would also be reduced. Consumptive uses would ultimately lower the water levels of Lake Erie, thus having a similar effect as limited regulation.

6.2 Environmental Evaluation

6.2.1 Introduction

The environmental impact of limited regulation of Lake Erie could be very broad, including impacts on water quality, wildlife/wetlands, and fish. The following discussion presents, for each of the above study areas, the evaluation of the effects of water level and outflow changes resulting from Plans 6L, 15S, and 25N.

Appendix F - Environmental Effects contains more detailed information concerning the environmental evaluation.

Owing to time and resource constraints, the analysis can only be considered preliminary in nature. Observations were often drawn from an insufficient data base, resulting in qualitative assessments in some areas. The effects identified through this analysis would have required a full investigation had limited regulation of Lake Erie demonstrated to be economically feasible. The geographic coverage was generally limited to the lower Great Lakes; i.e., from Port Huron, Michigan - Sarnia, Ontario to the New York State - Province of Quebec border.

6.2.2 Water Quality

Water quality characteristics that could be affected by regulation include: Lake Erie hypolimnion, nearshore turbidity, embayment pollution concentration, Cladophora growth, waste outfall dispersion, lakewide phosphorus concentrations, and general water quality. Limited regulation of Lake Erie would impact on these parameters both in adverse and beneficial

fashions, not only locally, but possibly on a system-wide basis. Construction of regulatory or remedial works and their operation could also lead to water quality degradation at the site.

Table 56 shows the areas where the above characteristics were studied. It also summarizes the various methodologies and assumptions employed and also defines the areas and time periods considered in the investigation.

Systemic Effects - Hypolimnion:

Limited regulation of Lake Erie could reduce the volumes of the hypolimnia of the Central and Eastern Basins of Lake Erie. It was calculated that as much as a 15 percent reduction in the volumes of the Central Basin hypolimnion could occur due to a 1 foot reduction in lake level. The corresponding reduction in the Eastern Basin would be as much as 4 percent. During the period of stratification (June through August), a 1-foot level reduction would occur approximately 20 percent of the time under Plan 25N. Plans 6L and 15S would cause proportionally smaller volume reductions.

Under Category 2 and 3 plans, the Lake Ontario hypolimnion would not experience any significant changes in volume due to its large initial volume and depth. The dissolved oxygen concentration in the hypolimnion would most likely remain unchanged under any of the plans.

Cool temperature, sufficient dissolved oxygen, and adequate space requirements (hypolimnion volume) are considered important to coldwater fish in summer. With respect to adequate dissolved oxygen, the Lake Erie Central Basin hypolimnion is of major concern. This hypolimnion is relatively small in volume, low in oxygen reserves, and has become anoxic over many square miles in prior years.

For the purpose of this evaluation, it was hypothesized that a lowering of water levels due to regulation would produce a reduction of hypolimnion thickness of an equal amount. As a result, for any given year under a proposed regulation plan, the thickness of the epilimnion (the warm surface layer) and the thermocline (the transition zone between the epilimnion and hypolimnion) would not be affected, as their formation is primarily dependent upon climatic conditions such as winds, temperature, and amount of solar radiation. Since the epilimnion and thermocline thickness would remain unchanged, the reduction in lake volume would originate from the hypolimnion.

The dissolved oxygen concentration of the Central Basin hypolimnion has been investigated sporadically since 1929. There is considerable controversy as to whether oxygen levels have been steadily declining, or merely fluctuating due to circumstances not yet completely understood. Recent model studies indicate that a reduction in hypolimnion thickness could result in a slightly lower oxygen reserve.

The Western Basin and Lake St. Clair hypolimnia were not considered since wind forces over these shallow waterbodies tend to maintain isothermal conditions, thereby preventing thermal stratification over any extended periods.

Table 56 - General Approach for Evaluation of the Impacts on Water Quality

Parameter/ Process	Procedure	Major Assumptions: General	Major Assumptions: Technical	Data Base: Geographic Coverage	Data Base: Temporal Coverage	Data Gaps
Hypolimnion	Linear regression technique (Oxygen depletion rate is a function of hypolimnion thickness)	Change in lake level equals change in hypolimnion thickness	- Constant hypolimnion temperature - Only hypolimnion thickness affects oxygen depletion	Lake Erie - Eastern and Central Basins	Eleven summer months between 1960 and 1977	Require BOC hypolimnion thickness for analysis
Turbidity	Linear regression model (turbidity is a function of lake level, toe-of-bluff wave and season)	Nearshore turbidity caused by shoreline erosion and bottom sediment resuspension	- Shoreline erosion a function of toe-of-bluff wave energy	Lake Erie - Port Stanley area and Ohio State area Lake Ontario - Grimsby area	Computer simulations of monthly turbidities for 1967-1976	Limited to data at WTP intakes No transposing of equations between reaches
Embayments	Simulate water exchange between lake and embayment plus consider reduced embayment volume	Embayments have vertical side slopes and unrestricted inlets.	- Embayments are instantaneously mixed box models - Hourly levels dominate exchange process	Lake Erie - Mentor, Lorain, and Dunkirk Harbours and Lake Ontario - Hamilton Harbour	Computer simulations of water exchange at LWD and below LWD	Not appropriate for marshes or embayment complexes
Cladophora	Annual production is a function of suitable substrate area	Nuisance and costs due to Cladophora is proportional to production	- Nutrients are not limiting - Production not influenced by turbidity - Yields remain constant	Lake St. Clair - lakewide Lake Erie - Bass Islands area and North Shore of Eastern Basin Lake Ontario - North Shore, east of Toronto	Annual production calculated for 1900 to 1976	
Waste Outfall Dispersion	Empirical Model Dispersion is a function of outfall depth	Only initial dilution affected. Conservative element considered for worst estimate	- Transpose laboratory results to lake conditions	Lake St. Clair - one outfall	Decrease in dispersion studies for 1-foot level decrease increments	
Phosphorus	Empirical Model P concentration a function of loading, water level, and flow	Total phosphorus reflects eutrophication	- Define nearshore zone by 10-metre contour - Retention coefficient proportional to lake level	Lake Erie - nearshore and lakewide Lake Ontario - nearshore and lakewide	1976 conditions examined with and without regulation	
General Water Quality	Empirical formulation	Conservative element observed under worst case conditions	- Chloride is totally conservative - Present pollutant loadings remain constant	Lake Erie - lakewide	Minimum and maximum range of flows, levels, and retention times	
General Water Quality	NOAA hydraulic transient model	Erosion and Dilution are only impacts	Erosion proportional to mean velocity	St. Lawrence River, Kingston to Cornwall	Maximum increase and decrease from mean monthly BOC flows	Modification of channel cross section due to dredging not defined
General Water Quality	Bottom sediment scour a function of water velocity	Contaminated sediments in Black Rock Canal	- Resuspension of bottom sediments proportional to mean velocity	Niagara River and Black Rock Canal	During construction and operation of structures	Insufficient bottom sediment data

Systemic Effects - Turbidity:

Lower lake levels would reduce the toe-of-bluff wave energy, reducing shoreline erosion, and consequently nearshore turbidity. Evaluation of the plans indicates mean decreases of turbidity on the order of 2 percent, 5 percent, and 11 percent for Plans 6L, 15S, and 25N, respectively. These values pertain to conditions at the Elgin Area Water Intake on the north shore on Lake Erie, and are not necessarily indicative of areas with nonerodible shorelines.

On Lake Ontario, the change in turbidity would be insignificant.

Turbidity is a reflection of material in suspension and is perhaps the most visible water quality characteristic. Generally, turbid waters are not aesthetically pleasing, and diminish the recreational potential of water bodies. In addition, increased expense is incurred to treat waters to domestically and sometimes industrially acceptable standards of clarity.

Nearshore turbidity is caused by tributary sediment loads, shoreline erosion, and resuspension of bottom sediments by wave action. For the purpose of this study the contribution of sediment from tributary sources and consequently, their contributions to turbidity were assumed unaffected by lake level.

Lower lake levels would reduce the toe-of-bluff wave energy. As a result, the quantity of shoreline material being eroded and contributing to nearshore turbidity would be reduced, especially along the highly erodible north shore of the Lake Erie Central Basin.

Empirical relationships, using the technique of linear regression analysis, were developed relating turbidity to wave energy reaching the toe-of-bluff in the Elgin area on Lake Erie. It was impossible to establish a relationsip with the September/October data. The data anomalies experienced during this period may be the result of autumn turnover. The months of December, January, and February were also excluded from the analysis since lake ice cover and shoreline ice either prevent waves from being generated or protect the shoreline from waves.

Table 57 refers to the Lake Erie central basin, north shore during the 1967-1976 period for which wave energy data are available. The decrease in turbidity over the period of evaluation would be 11 percent under Plan 25N. The maximum monthly decrease in turbidity would be 17 percent under Plan 25N. For Lake Ontario, a similar analysis was conducted with the raw water turbidity readings from the Grimsby Water Intake Plant.

Table 57 - Effect of Plans on Raw Water Turbidity at Elgin Area Water Treatment Plant on Lake Erie, 1967-1976[1]

	Plan 1977			
	BOC	6L	15S	25N
Mean Turbidity for Period of Evaluation (JTU)	22.3	21.8	21.2	19.8
Mean Turbidity Change for Period of Evaluation (JTU)	x	-0.5	-1.1	-2.5
Mean Percent Change	x	-2.2	-4.9	-11.0
Greatest Monthly JTU Change During Period of Evaluation	x	-3.0	-8.5	-16.7

1 Months of January, February, September, October, and December were excluded from calculations.

Under Categories 2 and 3, the change in mean annual turbidity on Lake Ontario over the 1967-1976 period of evaluation was less than 1 percent under all plans.

Systemic Effects - Embayments:

Any noticeable impacts due to lake regulation would be limited to the shallower embayments with a small lake/bay interface (Restricted). Although lower lake levels could enhance the beneficial effects of lake/bay exchange, the accompanying reduced embayment volumes would lead to increases in the embayment pollutant concentration due to the loss of dilution capacity.

The factors relevant to the dilution capacity of an embayment include its associated tributary stream, water exchange with the open lake, and the volume of water in the embayment.

The types of embayments which were assumed not to experience appreciable water quality changes due to reduced lake levels include embayments on tributary mouths (e.g., Port Burwell), commercial depth harbours (e.g., Hamilton), and embayments with a large lake/bay interface (Nonrestricted).

The water exchange between embayment and the open lake is affected by short-term lake level fluctuation caused by wind. The amounts exchanged during periods of short-term fluctuations are dependent upon the lake level, the embayment outlet characteristics, and depth. Model simulations demonstrate that lower lake levels tend to enhance the effects of water exchange between the lake and embayment. With lower levels, the lake water which is forced into the embayment by wind setup represents a greater proportion of the existing embayment volume. Embayment water quality would be beneficially influenced by the larger proportion of lake water composing the embayment volume.

On the other hand, a permanent reduction in embayment volume due to regulation would have adverse effets. It was assumed that the volume loss and/or dilution capacity loss in an embayment with vertical sides is directly proportional to the change in water depth. Thus a 1 foot lowering in an undisturbed 6 foot-deep bay would increase any pollutant concentration by about 17 percent, assuming a constant pollutant input to the bay. This condition could become critical in the event of a "slug" pollutant load into the embayment, such as an accidental spill.

Tables 58 and 59 show the opposing effects of lake/bay water exchange and the reduced embayment volume. For example, consider a restricted embayment with a mean water depth of 6 feet subjected to Plan 25N. In the event of an instantaneous pollutant load, an immediate 10.9 percent increase in embayment pollutant concentration would be realized due to a decreased dilution capacity (volume loss). However, the lake/bay water exchange under regulation would reduce embayment pollutant concentration by only 0.7 percent, but only during the period of the pertinent setup. The latter percentage can change depending upon the severity of the setup. In the example cited, both conditions working concurrently under Plan 25N would produce a 10.2 percent net polutant increase in the bay. The wind can also setup in the opposite direction forcing greater amounts of water out of the bay and further decreasing bay dilution capacity. In such instances, the adverse effects on an instantaneous pollutant load would be additionally augmented. In restricted bays deeper than 12 feet, the effects of the lake/bay exchange become inconsequential while the effects of embayment volume loss, although declining, remain appreciable.

In Lake Erie, shallow embayments with restricted mouths where dilution capability may be affected by regulation include: Sandy Creek, Catawba West, Middle, and East Harbour, Sandusky Bay, Northeast Yacht Club, Mentor Harbour, Erie Harbour, Colchester, Port Dover, and Sturgeon Creek.

In Lake Ontario, the general increase in the mean water level under both Categories 2 and 3 would increase the quantities of water available for dilution within the embayment.

Systemic Effects - Cladophora:

The implementation of Plan 25N would likely result in a 2 percent mean annual increase in Cladophora production on Lake Erie. The increases would occur primarily in the Eastern and Western Basins of Lake Erie. The same plan would result in no appreciable long-term change in Cladophora production on Lake Ontario.

The primary cause of excessive Cladophora production on the Great Lakes is overenrichment with nutrients from pollution. However, basic production requirements include available substrate and light availability both of which are influenced by lake levels. Lowering lake levels would alter the suitable substrate area available for Cladophora growth. At the same time, decreased turbidities due to lower lake levels would result in greater water clarity and consequently, increased light penetration. The increased light intensity could stimulate Cladophora production. Light availability was not considered

Table 58 - An Example of the Effect of Water Exchange on Embayment Pollutant Concentrations Due to Wind Setup Under Regulation

BOC Embayment Mean Water Depth (feet)	Percent Decrease Over BOC Concentration Due to Indicated Mean Water Level Decrease (d)[1]		
	6L d = 0.09 ft.	15S d = 0.23 ft.	25N d = 0.59 ft.
3	0.3	0.9	2.5
6	0.1	0.3	0.7
12	0.0	0.1	0.2
18	0.0	0.0	0.1

1 The above example assumes the following conditions:

Wind Setup = 1.0 foot
Vertical Littoral Zones
Initial Embayment Concentration Twice Lake Concentration

Table 59 - An Example of the Embayment Pollutant Concentration Increase Due to Reduced Dilution Under Instantaneous Loading

BOC Embayment Mean Water Depth (feet)	Percent Increase Over BOC Concentration Due to Indicated Mean Water Level Decrease(d)[2]		
	6L d = 0.09 ft.	15S d = 0.23 ft.	25N d = 0.59 ft.
3	3.1	8.3	24.5
6	1.3	3.8	10.9
9	1.0	2.6	7.0
12	0.8	2.0	5.2
18	0.5	1.3	3.4

2 The above formulation assumes vertical littoral zones in the embayment and an initial pollutant concentration of C* = 0.0 mg/l.

in this assessment because of a lack of adequate data. The evaluation was based upon increased substrate alone.

Table 60 indicates the change in growth for Lake Erie for both the north shore of the eastern basin and the Bass Islands region. For Plan 25N, the mean annual increase in Cladophora production would be 2 percent with a possible local maximum annual increase of 14.1 percent for the Bass Islands Region and 6.0 percent for the Eastern Basin. The effects of Plans 6L and 15S would be slightly less than those of Plan 25N.

Table 60 - Mean Annual Cladophora Production (tons/year) and Percentage Increase Over Basis-of-Comparison for Lake Erie, 1900-1976

Plan	Eastern Basin	Bass Islands	Total
Basis-of-Comparison	9,898	13,012	22,910
6L	9,910 (+0.1%)	13,081 (+0.5%)	22,991 (+0.3%)
15S	9,931 (+0.3%)	13,194 (+1.4%)	23,125 (+0.9%)
25N	10,006 (+1.1%)	13,362 (+2.7%)	23,368 (+2.0%)

A similar analysis of Category 2 and 3 plans on Lake Ontario indicates that no appreciable mean annual change in production would result.

Systemic Effects - Waste Outfall Dispersion:

No significant changes in dilution characteristics would occur at outfalls with diffusers due to lake regulation. These outfalls constitute a major portion of all outfall types. For outfalls with no diffusers, the decrease in dilution characteristics would be less than 2 percent.

In general, the design characteristics of the outfall regulate initial dilution, and lake processes influence subsequent dispersion. A maximum 2 percent reduction in initial dilution is predicted for outfalls with no diffusers. Outfalls operated with diffusers would not be influenced by lake level regulation. Some aesthetic problems might be realized for surface or near-surface outfalls since lowering of the lake level by as much as 1 foot might expose outfall heads and associated discharges.

Systemic Effects - Phosphorus:

The rate of total phosphorus inputs to Lake Erie could be reduced as a result of a reduction in the rate of erosion. However, most of the phosphorus contained in erodible shoreline is not biologically available. The effect of regulation, if any, would be to retard slightly the eutrophication process in that lake.

Any changes in lakewide phosphorus concentrations would be negligible for reduced lake levels and residence times.

Systemic Effects - General Water Quality:

General Lake Erie water quality would not be significantly altered by limited regulation of Lake Erie.

Lakewide water quality was analyzed by considering a conservative element (chloride). It was determined that for 2 years, 1974 and 1976, a 1-foot lowering of Lake Erie would amount to an increase of about 0.3 milligram per litre in the chloride concentration. Other conservative parameters such as sulfate, carbonate, bicarbonate, dissolved metals, etc., would be affected similarly. Only under Plan 25N would concentration increases of this magnitude be experienced. In light of this, the impacts of the other two plans would be negligible.

Table 61 is a summary of the foregoing evaluation of water quality characteristics for Plans 6L, 15S, and 25N.

Systemic Effects - St. Lawrence and Niagara Rivers:

Changes in St. Lawrence River water quality due to regulation could not be predicted with confidence. Under Category 1, Plan 25N would result in higher frequency of occurrence of high Lake Ontario outflows. Under Category 2, the frequency of occurrences of high outflows would be further increased. However, the range of extreme outflows would be reduced. Under Category 3, there would also be an increase in the frequency of occurrence of high Lake Ontario outflows compared to either the basis-of-comparison or the adjusted basis-of-comparison.

The application of the NOAA Upper St. Lawrence River Hydraulic Transient Model indicates that small increases in mean channel velocity would occur under both Categories 1 and 2. The small increases would not appear to be sufficient to cause any alteration in existing river bed scouring patterns considering the nature of the non-lake area bottom sediments (Bedrock-glacial till). Under Category 3, channel enlargements were examined in the regulatory works study in order to increase the channel discharge capacities. The effects on flow resulting from channel enlargement and limited regulation of Lake Erie could not be precisely evaluated without detailed field and laboratory investigations.

While no site specific analyses were conducted, it is possible that effluent plume dispersion would be altered, generally being extended longitudinally and compressed laterally.

Construction of remedial works needed under Category 3, would result in short-term, site-specific increases in turbidity.

Structural Effects - Niagara River Regulatory Works:

Water quality degradation associated with the Niagara River structure would be confined to the period of construction only. Regulation Plans using

Table 61 - Summary of Systemic Effects of Regulation Plans on the Water Quality Characteristics in Lake Erie

Characteristics	Probable Effects	Plan 6L	Plan 15S	Plan 25N
Hypolimnion	Onset of stratification affected by depth of water column.	Negligible	Negligible	Negligible
	Reduction in hypolimnion volume:			
	Western Basin	No Hypolimnion	No Hypolimnion	No Hypolimnion
	Central Basin	Unknown Significance	Unknown Significance	<15% Reduction
	Eastern Basin	Unknown Significance	Unknown Significance	3.4% Reduction
	Change in dissolved oxygen concentration.	Negligible	Negligible	Negligible
Turbidity	Reduction in mean annual turbidity. (Elgin Area 1967-1976)	2% Reduction	5% Reduction	11% Reduction
Embayments	*Increase in pollution concentrations* due to lowering effect. (Assuming depth of 6 feet.)	1.5%	4.0%	10.9%
	Decrease in pollutant concentrations due to wind setup. (Assuming BOC depth of 6 feet.)	0%	0.2%	0.7%
	(For embayments deeper than 6 feet.)	Negligible	Negligible	Negligible
Cladophora Production	Increase in mean annual production:			
	Western Basin (Bass Islands)	0.5%	1.4%	2.7%
	Central Basin	No Significant Growth	No Significant Growth	No Significant Growth
	Eastern Basin (North Shore)	0.1%	0.3%	1.1%
Waste Outfall Dispersion	Effects restricted only to outfalls without diffusers.	Negligible	Negligible	Negligible
Phosphorus	Reduction in sediments from shoreline erosion, lakewide.	Negligible	Negligible	Negligible
General Water Quality	*Inflows, outflows, and detention period.*	Negligible	Negligible	Negligible

the Black Rock Canal would increase the potential for introducing contaminated canal sediments into the Niagara River, during construction and subsequent operation.

6.2.3 Wildlife/Wetlands

The evaluation of the effects on wildlife of the plans for limited regulation of Lake Erie was made by examining the changes in habitat that could occur as a result of altered lake level regimes. The greatest impact of changes in lake levels would occur along the shore and shallow areas of the Great Lakes where wetlands are the primary type of wildlife habitat.

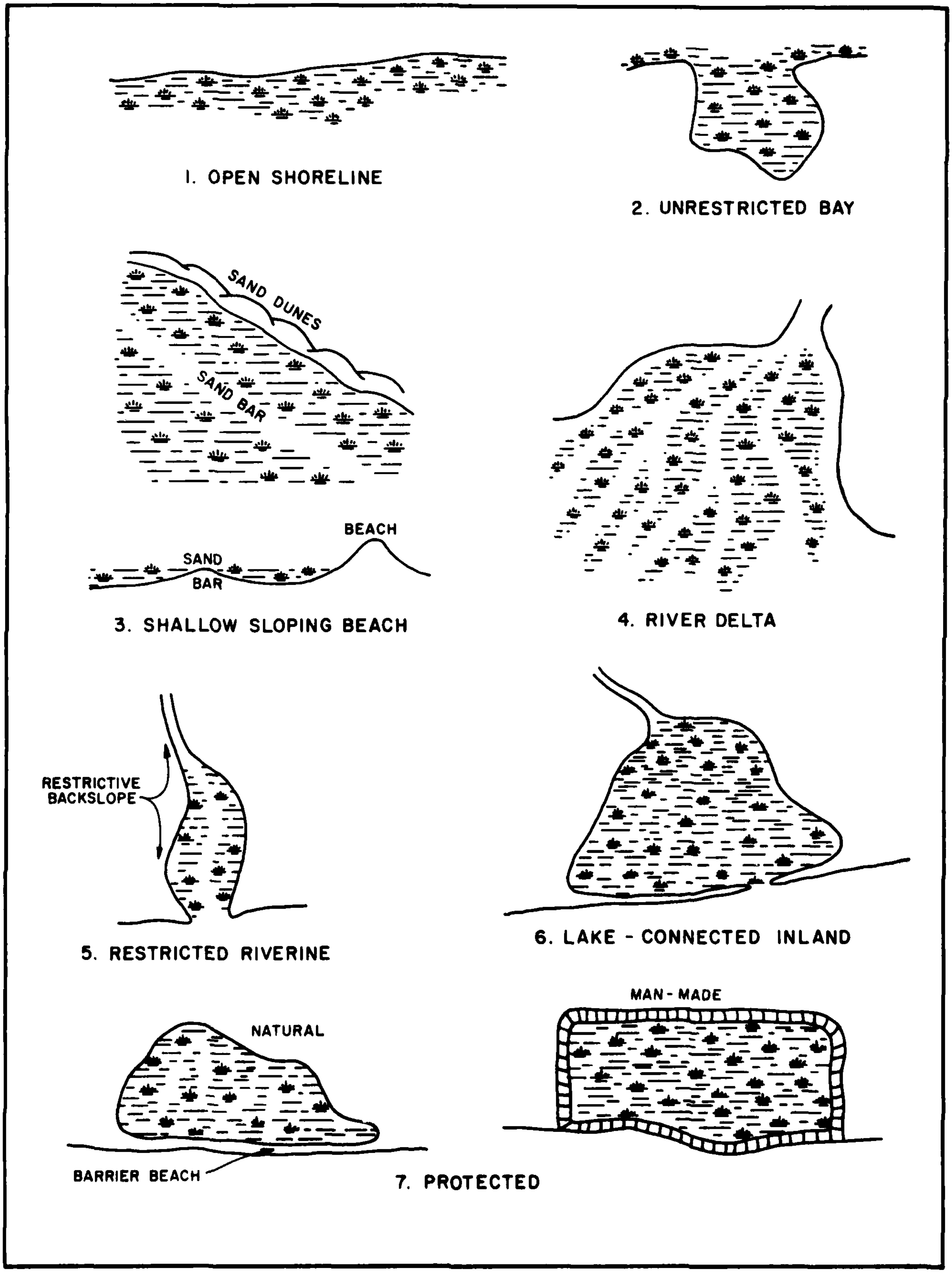
The evaluation was directed principally to Lakes Erie and St. Clair (including the Detroit and St. Clair Rivers). These lakes contain a large portion of the most desirable wetland habitat in the Great Lakes system and would experience the most severe changes in water levels under limited regulation of Lake Erie. The predicted impacts of altering water levels on Lake Ontario and the St. Lawrence River to the Ontario/Quebec Border were also addressed, as were the effects of structural and remedial works in the Niagara and St. Lawrence Rivers.

The wildlife evaluation was largely qualitative. Some of the predicted impacts were based on the opinions of biologists familiar with Great Lakes wetlands, not on detailed scientific studies. Detailed information on bottom contouring of wetlands was not available and information linking changes in vegetation in the Great Lakes wetlands to water level fluctuations is very limited. Studies correlating the responses of wildlife species with water level fluctuations and with the resultant vegetative changes in the wetlands of the system are almost nonexistent.

The wildlife evaluation predicts the effects that the three regulation plans could have on the long-term (i.e., over 4 years) and short-term (i.e., 4 years or less) vegetative structure of shoreline wetlands, their value as wildlife habitat and on specific wetland types.

As a first step in the wildlife evaluation, the shoreline wetlands in the study area were inventoried according to a classification scheme designed for this study. Seven wetland types, illustrated in Figure 32, have been defined based on physical characteristics and general predicted responses to water level changes. The seven types represent wetland situations ranging from completely open to lake effects (1) to completely protected (7). The results of the inventory showing the wetland area of the lower Great Lakes by wetland type and water body are shown in Table 6 (Section 2.4.2).

The productivity, biological composition, and size of the wetlands of the lower Great Lakes are highly dependent on the long-term water level regime. The regulation plans would change the long-term water levels, thereby altering wetland conditions. The evaluation focused on the hydrologic characteristics most meaningful to wetlands: long-term annual mean; range of fluctuation; high water levels; low water levels; frequency and duration of high and low water levels; and seasonal distribution (timing) of water.



GREAT LAKES WETLAND TYPES

FIGURE 32

For this study, all shoreline wetlands were considered to consist of four major vegetative zones:

1. Open-Water/Floating-Leaved/Submergent (e.g., pondweeds, coontail);

2. Emergent (e.g., cattail, bullrush);

3. Sedge/Meadow (e.g., sedge, beggar tick, canary grass); and

4. Shrub/Tree (e.g., willow, dogwood sweetgale).

These zones shift position or change in size in response to the above-noted hydrologic characteristics. The effects of the regulation plans were evaluated by predicting the types of zone shifts and alterations in vegetative composition that could be induced by water level changes occurring under each plan.

The relative area which each of the four vegetative zones comprises in any wetland, affects its value for wildlife, fish, and other aquatic organisms. The effects of the regulation plans on wildlife were inferred by examining the zone shifts which would occur under each of the plans.

In assessing the systemic impacts of implementing the regulation plans, the following assumptions were made:

1. The existing Great Lakes shoreline wetlands have evolved in response to historic water level regimes and environmental conditions, including man-induced changes;

2. The shoreline wetlands of the Great Lakes benefit biologically from, and require, fluctuating lake levels to maintain their diversity and productivity;

3. Changes in wetland vegetative composition and area will affect their value to wildlife; and

4. Wetlands having the same wetland type will react similarly to the same water level regime alteration.

The evaluation of localized effects of regulatory works in the Niagara River and of remedial works in the St. Lawrence River focued on the effects of construction, operation, and maintenance of these works.

Systemic Effects:

It is predicted that, with regard to Lakes Erie and St. Clair, all regulation plans would in the long-term, cause an increase in sedge/meadow and emergent-dominated wetlands, with concomitant decreases in the diversity of vegetation and in diversity and abundance of wetland-dependent wildlife species. The implementation of the regulation plans would place a potentially severe stress on wildlife habitat already under pressure from agriculture, development, and pollution.

The shoreline wetlands exhibit vegetative zone shifts in response to long-term fluctuation of lake levels. In general, low water conditions will produce an invasion of the sedge/meadow by shrubs, a displacement of emergents by the sedge/meadow, and a decrease in open-water and associated aquatic communities. High water conditions will produce an increase in open-water aquatics, as other communities decrease. A hemi-marsh condition (50 percent open water/50 percent wetland vegetation) is considered by many experts to be the optimum wetland producing the greatest habitat diversity for wetland-dependent wildlife.

Table 62 describes the general responses of wetlands to alterations in the specific water level parameters considered in this evaluation as having a potential to affect wetlands. Comments are directed primarily to the wetlands of Lakes Erie and St. Clair, with some discussion of Lake Ontario and the St. Lawrence River.

Fluctuations in water levels comparable to recent historical conditions (i.e., last 20 years) are required to maintain the long-term productivity and diversity of the wetlands. High water (i.e., above the long-term mean) produces habitat approaching the hemi-marsh which benefits a diversity of wildlife species such as waterfowl, muskrats, black terns, herons, invertebrates, amphibians, and reptiles. High water could also facilitate the interchange between the lake and the wetland, and thus permit fish spawning (e.g., northern pike) as well as the rearing of forage fish.

Low water conditions (i.e., water levels below the long-term mean) encourage the predominance of the sedge/meadow and dense emergent zones. During extended periods of low water, the diversity of wildlife species decreases, with habitat conditions favoring red-winged blackbirds, short-billed marsh wrens, rails, white-tailed deer, cottontail rabbits, and small rodents.

Systemic Effects - Lake Erie, Lake St. Clair, St. Clair River, Detroit River:

a. General Responses of Seven Wetland Types to Regulation:

Lake-connected inland, shallow-sloping beach, and restricted-riverine wetlands could experience severe vegetative zone shifts that would reduce the wildlife value of those areas. Open-shoreline, unrestricted-bay, river-delta, and protected wetlands should experience less severe vegetative shifts. Even so, examination of vegetative zone area changes in a specific river delta wetland discloses some significant acreage changes.

The type and degree of response of each of the wetland types to water level changes are dependent to a large extent on the soil, bottom contour and back slope characteristics of each wetland. The regulation plans, with respect to Lakes Erie and St. Clair would lower high water levels, and slightly lower the long-term mean and minimum water levels. The plans also would reduce the range of fluctuation and the frequency and duration of high water levels, but would increase the frequency and duration of low water levels.

Table 62 - General Responses of Wetlands to Long-term Changes in Water Level Parameters

Long-Term Annual Mean	Higher	Hydrophytic vegetative characteristics will become pronounced, with a general improvement of habitat conditions for wetland-dependent wildlife.
	Lower	In general, a wetland will exhibit more mesophytic vegetative characteristics, with a resultant decrease in habitat suitability for wetland-dependent wildlife species.
Range of Fluctuation	Greater	A moderate increase in range may increase the wetland area (depending on backslope) and would encourage plant species diversity.
	Reduced	A reduced range will result in a reduced wetland area and encourage a more dense growth of emergent vegetation and less species diversity.
High Water Levels	Higher	A slight increase of high water level may increase the wetland area and benefit wetland-dependent wildlife; however a large increase could eliminate large stands of emergents, create extensive open areas, and adversely affect wildlife.
	Lower	A loss of wetland would occur along the landward edge. with a general reduction of the open water/submergent zone.
Low Water Levels	Higher	A general increase of level at which low water levels occurred would reduce the predominance of the sedge/meadow zone at low water.
	Lower	The mesophytic characteristics of wetlands would become more pronounced, with an increase of the sedge/meadow and emergent vegetation zones.
Frequency & Duration of High Water Levels	Increased	An increased frequency and duration of high water levels would, in general, promote greater interspersion of vegetation and open water and reduce the extent of the sedge/meadow zone. However, at extreme high levels, an increased incidence of emergent die-back would be detrimental.
	Reduced	A reduction in the frequency and duration of normal high water levels would encourage an invasion of a wetland's landward edge by shrubs and increase the area of the sedge/meadow zone, thereby reducing the wetland's value to wetland-dependent wildlife species.
Frequncy & Duration of Low Water Levels	Increased	The developemnt of denser stands of emergents and an expansion of the sedge/meadow zone would occur.
	Reduced	A reduction in the predominance of the sedge/meadow zone at low water levels would result.
Altered Seasonal Distribution of Water		The reproduction and successful growth of wetland vegetation fish, and wildlife would be adversely affected if changes in the seasonal regime of high and low water levels occurred.

Table 63 presents a discussion of the general responses to the regulation plans for each of the seven wetland types. Comments for Lake St. Clair, Lake Erie, St. Clair River, and Detroit River are applicable to all regulation plans. Comments for Lake Ontario are in reference to Category 2 plans.

b. Predicted Vegetation Changes in Specific Wetlands Due to Regulation:

The general trend in any of the specific wetlands examined in Lakes St. Clair and Erie would be a decrease in the area occupied by the open-water/floating submergent vegetation with a lowering of water levels. There would be a corresponding increase in emergents and/or sedges.

Based on a study by Jaworski et al. (1979), and also work by Bayly (1979), and Snell and Donaldson (1979), graphs were developed to illustrate changes in vegetative zones resulting from water level changes for seven wetlands. As an example, Figure 33 shows the percent of each of the four vegetative types on Dickinson Island in Lake St. Clair; a 2,800-acre River Delta wetland. There are a total of 22,672 acres of this type of wetland on Lake St. Clair.

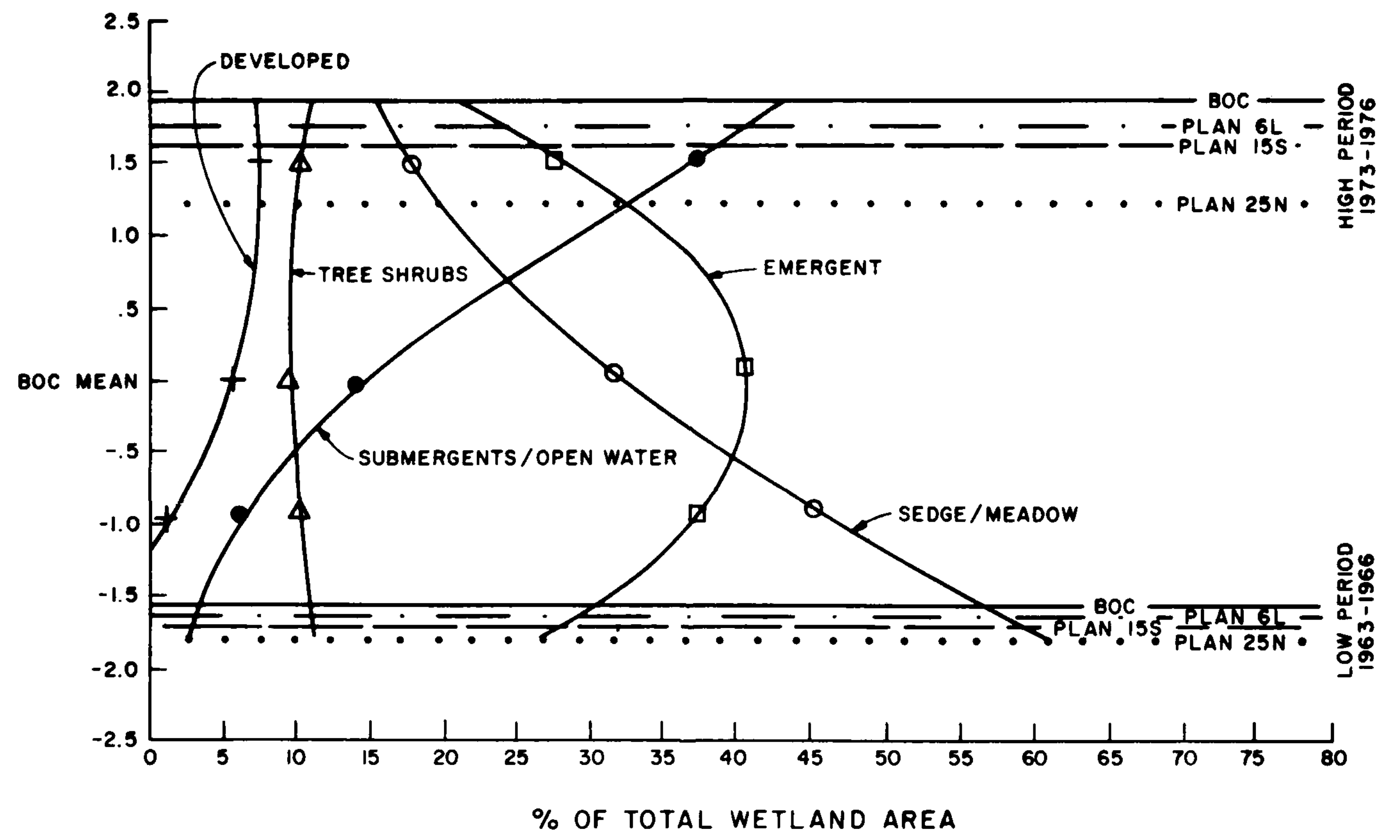
The figure shows the percent of the total wetland area (horizontal axis) in each vegetative zone which would result at various water levels about the basis-of-comparison long-term annual mean (vertical axis). Each symbol on the curved lines represents a field measurement taken from Jaworski et al. (1979). The lines connecting the symbols represent each of the vegetative zones most likely to occur at various water levels. The high and low water levels for the basis-of-comparison and for each regulation plan, as depicted on the illustration (Figure 33), are an average of the 4 consecutive years of highest or lowest water levels in the last 20 years (1973-1976, 1963-1966, respectively). A 4-year time period was selected since it takes 3 to 5 years of sustained water levels for the vegetative structure to develop.

Table 64 shows, for Dickinson Island, the area of each vegetative zone and the percent of the total area of the wetland that each zone would represent under basis-of-comparison conditions. Areal changes, as a loss (-) or gain (+), of each of these vegetative zones due to each of the regulation plans are shown on Table 65. It can be seen that, compared to the basis-of-comparison, all regulation plans would decrease open-water aquatics and increase sedge/meadow and emergent zones for high, mean, and low water periods.

Graphical presentations for seven additional wetlands are included in the Wildlife chapter of the Environmental Effects Appendix.

Table 63 - General Response of Wetland Types to Regulation

Wetland Types	Lowered Water Levels Lakes St. Clair and Erie	Increased Water Levels Lake Ontario
Open Shoreline	A lowering of water levels would result in a lakeward shift of vegetation zones, leaving a dry zone (shrub/tree) at the landward edge. Emergents and sedge/meadow zones would become more prevalent.	The magnitude of change of Lake Ontario water levels, as a result of proposed regulation plans does not permit a distinction to be made between wetland types.
Unrestricted Bay	Lowered water levels would encourage the growth of dense emergents at the expense of open-water aquatics.	
Shallow-Sloping Beach	A lowering of water levels may result in vegetation zone shifts over large areas, with extensive sections of the wetlands exhibiting more mesophytic vegetative characteristics. Critical wildlife areas could experience significant damage.	In general, a slight improvement of wetland conditions may occur with the predominance of sedge/meadow zones reduced at low water periods. However, at time of high water, an increase may prove detrimental in some wetlands, with the dieback of emergent vegetation increasing to too great a degree.
River Delta	Lower water levels would cause a lakeward shift of vegetation zones, but sedge/meadow zones would be more prevalent at the expense of open-water aquatics.	
Restricted Riverine	These wetlands would become dominated by emergent and sedge/meadow zones in response to lowered water levels.	
Lake-Connected Inland	Lowering of the long-term water levels would result in the loss of wetland along the landward perimeter. Sedge/meadow and emergent zones would become prevalent for longer periods and diversity of wildlife would be reduced. Effects of lowered lake levels may be most severe in this wetland type.	Lake-connected inland wetlands may experience detrimental diebacks of emergent vegetation during high water levels.
Protected	Natural. These wetlands would exhibit denser emergent vegetation and an increase in the extent of the sedge/meadow zones. Dyked. These wetlands could shift to denser emergent vegetation with extreme lowering. Management techniques could offset slightly lowered water levels.	



EXPECTED VEGETATIVE STRUCTURE AT VARIOUS LAKE LEVELS
DICKINSON ISLAND MARSH - LAKE ST. CLAIR

FIGURE 33

Table 64 - Area of Vegetative Zones for Dickinson Island: A River Delta Wetland in Lake St. Clair

	Basis of Comparison					
	High Period (1972-1973)		Mean		Low Period (1963-1966)	
Vegetation Type	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	308	11	252	9	308	11
Sedge/Meadow	448	16	896	32	1,568	56
Emergents	588	21	1,120	40	840	30
Open Water/Submergent/ Floating	1,232	44	392	14	84	3
Developed 1/	224	8	140	5	0	0
Total	2,800	100	2,800	100	2,800	100

1/ Changes in the area of developed land are not related to water level changes. They reflect the amount of development that existed during the time period selected to represent high, mean, and low water levels.

Table 65 - Areal Changes in Vegetative Zones for Dickinson Island: A River Delta Wetland in Lake St. Clair

(a) High Period (1973-1976)

Vegetation Type	Plan 6L Acreage Difference	Plan 6L Percent of Change	Plan 15S Acreage Difference	Plan 15S Percent of Change	Plan 25N Acreage[1/] Difference	Plan 25N Percent of Change[2/]
Trees/Shrubs	0	0	0	0	-28	-9
Sedge/Meadow	0	0	+28	+6	+84	+19
Emergents	+84	+14	+140	+24	+336	+57
Open Water/Submergent/ Floating	-84	-7	-140	-11	-308	-25

(b) Long-Term Annual Mean

Vegetation Type	Plan 6L Acreage Difference	Plan 6L Percent of Change	Plan 15S Acreage Difference	Plan 15S Percent of Change	Plan 25N Acreage[1/] Difference	Plan 25N Percent of Change[2/]
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	+28	+3	+28	+3	+140	+16
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	-28	- 7	-28	-7	-112	-29

(c) Low Period (1963-1966)

Vegetation Type	Plan 6L Acreage Difference	Plan 6L Percent of Change	Plan 15S Acreage Difference	Plan 15S Percent of Change	Plan 25N Acreage[1/] Difference	Plan 25N Percent of Change[2/]
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	+28	+2	+84	+5	+112	+7
Emergents	-28	-3	-56	-7	-84	-10
Open Water/Submergent/ Floating	0	0	-28	-33	-28	-33

1/ Acreage Difference = (A' - A) X total wetland acreage.

2/ Percent of Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under Basis-of-Comparison.

Note: In each of the above footnotes, A' and A are derived from graphs such as preceding Figure 33.

c. Vegetative Zone Shifts and Effects on Wildlife:

In general, the predicted shift to sedge/meadow plant communities, at the expense of reducing the interspersed open-water aquatics and emergent zones, would decrease the diversity and abundance of wetland-dependent wildlife species.

The value of the wetlands to recreationally-and commercially-important species, such as migratory waterfowl and muskrats, would decrease. The low-water conditions created by the regulation plans could stimulate the diking of additional wetlands. This would further reduce the number of wetland areas available to fish as spawning and nursery areas. Ultimately, the diked wetlands would more likely be drained for alternate uses and lost to most wildlife altogether.

The predicted increase of sedge/meadow and emergents zones would benefit red-winged blackbirds, swamp sparrows, yellowthroats, and some terrestrial species (white-tailed deer, cottontail rabbit), while wetland-dependent species such as migratory waterfowl, muskrats, coots, gallinules, and black terns would suffer. The primary importance of the Great Lakes shoreline wetlands for waterfowl is as migration-staging habitat. Good quality staging areas require "hemi-marsh" conditions, which provide adequate food and cover plants. Lower water levels would result in poorer marsh quality and therefore, less use by migrating waterfowl. This would likely reduce the hunting and viewing opportunities in the Great Lakes shoreline wetlands. A slight increase in the number of nesting waterfowl might be noticed as a result of increased sedge/meadow zones, but these increases would be more than offset by a reduction in the quality of staging habitat.

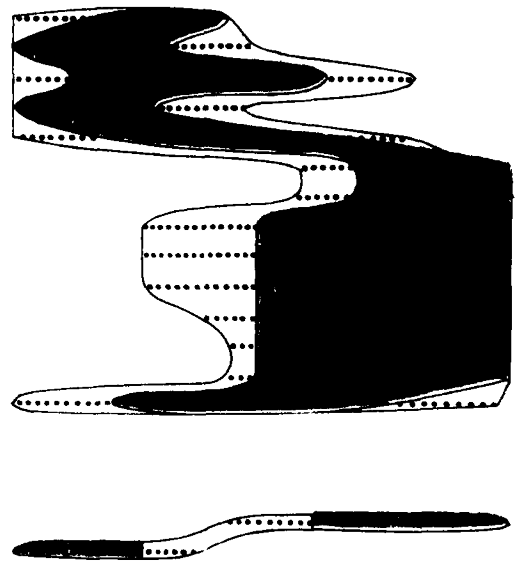
Table 66 illustrates the points made above by describing wildlife use of coastal wetlands at low and high water levels.

In reference to Lakes Erie and St. Clair, "much of the diking of coastal wetlands by private and public shooting clubs was carried out during the low-water periods (i.e., 1930's and 1960's) when dense cattail and widespread sedge communities reduced the quality of waterfowl and muskrat habitat" (Jaworski et al. 1979). Diked wetlands with a much higher market value than undiked wetlands, are more likely to be drained for an alternate use, usually agriculture. Along the eastern shoreline of Lake St. Clair (Thames River to Chenal Ecarte), from 1965 to 1978, 25 percent of the existing wetlands were destroyed, primarily by agricultural drainage. Of the 1,179 acres that were lost, 91 percent were diked wetlands.

It therefore, appears that the implementation of any of the regulation plans would also contribute to the destruction of additional wetland acres on Lakes Erie and St. Clair.

Table 66 - Wildlife Use and Other Functions of Coastal Wetlands at Low and High Water Levels (From Jaworski et al, 1979)
(Key: Most Desirable, Acceptable)

Use/Function of Wetlands	Low Water	High Water
a. Use by Wildlife:		
Blue-winged teal (breeding)		
Red-winged blackbird		
Mallard (breeding)		
Short-billed wren		
Muskrat		
Black tern		
Yellowheaded blackbird		
Great blue heron		
Belted kingfisher		
Crayfish		
Frogs and turtles		
Fish spawning (N. Pike)		
Forage fish		
Dabbling ducks (feeding)		
b. Other Functions:		
Hemi-marsh		
Dominance of land drainage		



Systemic Effects - Lake Ontario:

All three Category 2 regulation plans would produce changes of a similar magnitude to the Lake Ontario wetlands. The regulation plans would raise the high water levels and raise slightly the long-term mean and low water levels. The plans would also increase the frequency and duration of high water levels, but would reduce the frequency and duration of low water levels.

Overall, the impacts on Lake Ontario may be regarded as indeterminable to slightly beneficial for wetlands and wetland-dependent wildlife. In general, the proposed changes to the water level regime would result in less dense growths of emergents and sedge/meadow during the low and mean water periods of the long-term cycles. However, the increased high levels would increase the die-back of emergents in the short-term.

Plan 25N would reduce the already limited long-term fluctuation range that would be experienced under the basis-of-comparison. This would likely encourage the formation of a less diverse wetland, both in terms of vegetative composition and wildlife.

The predicted small changes to Lake Ontario water levels, plus the limited information available for Lake Ontario wetlands, do not allow a more detailed examination of the impacts of Lake Erie regulation on the Lake Ontario environment.

Systemic Effects - St. Lawrence River:

Plan 25N (Category 2) would increase the frequency of occurrences of high water levels in the downstream sections of the St. Lawrence River. These increases would in general, increase the short-term die-back of emergent vegetation in the shoreline wetlands. Wildlife species dependent upon emergent vegetation for nesting and feeding would suffer in the short-term. Low and mean water level conditions would be minimally affected by Plan 25N. Plans 15S and 6L would produce similar effects but of a smaller magnitude.

The water level fluctuations currently experienced in the St. Lawrence River are highly variable. This variability combined with the relatively small increases in water levels predicted for even Plan 25N and the very limited information base for wetlands along the river does not permit detailed analysis of impacts on wetlands to be made within the constraints of this study.

Structural Effects - Niagara River Regulatory Works:

The impact of the Niagara regulatory structures, due to construction and operation, on wildlife would probably be minimal. Of the three regulation plans being evaluated, only Plan 25N involves major structures requiring extensive construction work (i.e., dredging and blasting of the Niagara River bottom, cofferdaming, etc.). During construction, an increase in turbidity and sediment load in the river would be expected. This increase in turbidity causing reduced light penetration could be damaging to the vegetation in the river itself reducing the attractiveness of these areas to wintering waterfowl.

Structural Effects - St. Lawrence River Remedial Works:

The required dredging along the St. Lawrence River for Category 3 does not directly involve any wetlands or known critical wildlife habitat. The effects, which would be direct removal of habitat, would be insignificant. There would also be increased turbidity and sediment load during initial dredging and maintenance operations which could be damaging to vegetation thereby affecting waterfowl habitat.

6.2.4 Fish

The changes in lake levels which result from limited regulation of Lake Erie, though small compared with recorded fluctuations, could have serious effects on fish, primarily in shallow inshore areas of the lakes and the connecting channels in the study area, and at the sites of the regulatory structures. The shallow-water environments are the most biologically productive areas of the Great Lakes system. These areas provide important

spawning, nursery, and feeding grounds which are essential to the maintenance of fish stocks. Some important shallow-water areas are Lake St. Clair, Lake Erie's western basin and Long Point Bay, the eastern basin of Lake Ontario, and the St. Lawrence River.

This evaluation was based on existing information. The determination of cause-effect relationships between water level changes and the impact on fish was based largely on inference and was qualitative rather than quantitative. Much of the available information on the Great Lakes fish stocks is not directly related to the evaluation of lake level changes due to regulation. There is a particular lack of information on the nearshore area and on how water level changes would affect the fish utilizing this very productive zone.

In the evaluation of the potential impacts that limited regulation of Lake Erie water levels would have on the fish resources of the lower Great Lakes and their connecting channels, readily available and pertinent data were reviewed. The sources of information included published scientific papers, unpublished documents, data banks, and expert opinions.

During this investigation, emphasis was placed on:

1. Identifying the requirements of fish populations in specific nearshore habitats, primarily wetlands and shallow embayments;

2. Identifying fish species sensitive to lake level changes, including those which require the cool waters of the hypolimnion in the summer; and

3. The localized impacts resulting from the regulatory structures in the Niagara River and remedial works in the St. Lawrence River.

The evaluation of systemic effects was based on the identification of the impacts of long-term (i.e., over 4 years) and annual water level changes in critical nearshore areas and on species sensitive to such level changes. Attention was focused on impacts due to changes in the long-term mean water level and in the frequency, duration, amplitude, and seasonal occurrences of high and low levels.

Since shoreline wetlands are important to the fish resource as food sources and habitat, a wetland review was incorporated into this evaluation. The impacts on fish from changes in water quality and hypolimnion volume as a result of regulation were also examined.

The long-term lowering of lake levels could cause loss of access to or impairment of open shoreline and lake-connected wetlands which are essential living areas (spawning, nursery, feeding, etc.) to many fish species. A loss of such areas could adversely impact the fish populations that are dependent on the nearshore zone.

A more detailed description of the fish studies performed to determine the impacts of limited regulation of Lake Erie can be found in the Fish Section of the Environmental Effects Appendix.

General Water Level and Flow Regime Parameters:

Based on analysis of recorded water level patterns and a review of the literature, the following factors were identified as important to the maintenance and development of the existing fish resource: seasonal occurrence of high and low water levels, long-term mean water level, extreme high and low levels, and long-term water level fluctuation range.

Major alteration of these cycles or conditions through regulation could have serious adverse effects on fish stocks and habitats.

The occurrence of the annual low water level, generally in December, January, or February, sets the stage for favorable conditions in the spring. Water levels artificially lowered further during this period would reduce the already limited habitat available to the many species that re-invade the nearshore zone once the ice cover forms.

The rise of water levels in the spring increases the availability of aquatic habitat thereby reducing competition for essential living areas (spawning, nesting, nursery, feeding, etc.). The timing of this rise is critical, especially for species such as northern pike and golden shiner which are dependent on plants for spawning. The rising levels also enhance nutrient release thereby increasing primary productivity and indirectly increasing fish production.

The range of the seasonal water level fluctuations is important to the ecology of the shoreline wetlands (see Section 6.2.3). These fluctuations rejuvenate the wetlands each year and prevent them from becoming choked with vegetation. These same conditions provide many benefits to nearshore fish communities. Fluctuating water levels keep the channels open into the wetlands providing fish with access to food and shelter. These channels also prevent wetland stagnation and oxygen depletion by permitting inflow of lake water, and allowing the passage of nutrients into the open-lake increasing primary productivity, thus indirectly aiding fish production.

Lowering the long-term mean water level could result in a permanent loss or impairment of nearshore spawning grounds and/or nursery areas. Lower lake levels would most likely reduce the availability of certain food sources by creating larger areas of emergents and smaller areas of submerged plants. The thermal regime of the shallow protected embayments (e.g., Rondeau Bay, Long Point Bay and parts of Sandusky Bay) could also be affected. The thermal changes could adversely affect the reproductive success and growth rates of the fish species utilizing these areas.

The historical frequency of occurrence and duration of periods of extreme high and low levels is important; particularly for the extreme lows. Any lowering of the extreme lows would reduce the availability of already limited shallow-water habitat. Also, the lowering of extreme low levels could result in increased wetland diking, thereby permanently removing additional wetland area as fish habitat.

The long-term (historical) range of fluctuation should be maintained. These fluctuations maintain the diversity of the wetlands by preventing plant succession. High water periods for 3-5 years open the marsh by causing die-offs of dense emergent and sedge vegetation and an invasion by open-water, submergent, and floating-leaved plants. Low level periods enhance the growth of emergents and sedges. The submergent and floating-leaved plants are more productive fish habitat. High waters allow fish to enter the wetland to use the area. A reduced range would encourage a more homogeneous vegetative community to develop which, if the range were reduced sufficiently, would revert to a mesophytic condition and eventually upland environment resulting in lost fish habitat.

Areas Sensitive to Water Level Changes:

Areas sensitive to water level changes include the Lake Erie wetlands, the western basin of Lake Erie, the Lake St. Clair wetlands, the Lake Ontario eastern basin, and the wetlands and shallow embayments of the connecting channels. In Lake Erie, the extensive littoral areas would be most affected by lake level changes. Long Point, Rondeau, Sandusky, and Presque Isle Bays are, due to their shallow nature and sand spit formation, areas very sensitive to water level changes.

Species Sensitive to Water Level Changes:

Fish show habitat specialization. Lake regulation could destroy or alter any of these preferred or essential habitats, thereby affecting particular species dependent upon the habitat. The importance of the effect upon the species depends on whether the species occasionally uses, prefers, or needs the habitat for survival.

Species susceptible to the changes in the nearshore habitats are listed in Table 67 according to habitat preference (i.e., spawning and nursery areas). This table identifies, from more comprehensive lists (see Fish Section of Environmental Effects Appendix), those fish species utilizing the nearshore zones and wetlands of the lower Great Lakes. Although species using these areas can be identified, information concerning whole life cycle requirements of many, especially the forage varieties, is severely lacking or nonexistent.

Systemic Effects - Lakes Erie and St. Clair:

It appears that Plan 25N could result in water level changes which adversely affect fish populations. Plan 25N has the potential to cause permanent displacement, impairment, or loss of essential living areas; limit formation of the hemi-marsh, a wetland condition favorable for fish; render spawning areas inaccessible during low water conditions and through increased diking of wetlands; and decrease the size of the Central Basin hypolimnion.

The effects on fish of water level changes due to Plans 6L and 15S are very difficult to evaluate. Their impacts on the fish resources would generally be of the same nature but proportionally less than those of Plan 25N.

Table 67 - A List of Species by Preferred Area and Habitat Type (Modified from Hartley and VanVooren, undated)

Species by Spawning Area: Shallow Protected, Sand-Mud, Silt with Vegetation	Species by Spawning Area: Shallow Protected, Sand-Mud, Silt Without Vegetation	Species by Nursery Area: Shallow Protected, Sand-Mud, Silt With Vegetation	Species by Nursery Area: Shallow Protected, Sand-Mud, Silt Without Vegetation
Banded Killifish	Alewife	Banded Killifish	Black Bullhead
Bigmouth Buffalo	Black Bullhead	Black Bullhead	Bluegill Sunfish
Black Bullhead	Bluegill Sunfish	Black Crappie	Bluntnose Minnow
Black Crappie	Bluntnose Minnow	Blacknose Shiner	Brindled Madtom
Blacknose Shiner	Bowfin	Bluegill Sunfish	Brook Silversides
Bluegill Sunfish	Brindled Madtom	Bluntnose Minnow	Brown Bullhead
Bluntnose Minnow	Brook Silversides	Bowfin	Carp
Bowfin	Brown Bullhead	Brindled Madtom	Channel Catfish
Brindled Madtom	Carp	Brook Silversides	Fathead Minnow
Brook Silversides	Fathead Minnow	Brown Bullhead	Gizzard Shad
Brown Bullhead	Gizzard Shad	Carp	Goldfish
Carp	Goldfish	Central Mudminnow	Green Sunfish
Central Mudminnow	Green Sunfish	Channel Catfish	Largemouth Bass
Fathead Minnow	Iowa Darter	Channel Darter	Mimic Shiner
Golden Shiner	Largemouth Bass	Fathead Minnow	Pumpkinseed Sunfish
Goldfish	Longnose Gar	Gizzard Shad	Smallmouth Bass
Grass Pickerel	Mimic Shiner	Golden Shiner	Spotfin Shiner
Green Sunfish	Mottled Sculpin	Goldfish	White Crappie
Gr. Sided Darter	Pumpkinseed Sunfish	Grass Pickerel	Yellow Perch
Iowa Darter	Smelt	Green Sunfish	
Lake Chubsucker	Spotfin Shiner	Gr. Sided Darter	
Largemouth Bass	Spotted Gar	Iowa Darter	
Muskellunge	White Crappie	Lake Chubsucker	
Northern Pike	Yellow Bullhead	Largemouth Bass	
Pugnose Shiner		Longnose Gar	
Pumpkinseed Sunfish		Logperch	
Quillback		Muskellunge	
Spotfin Shiner		Northern Pike	
Yellow Bullhead		Pugnose Shiner	
		Pumpkinseed Sunfish	
		Quillback	
		Spotfin Shiner	
		Spotted Gar	
		Tadpole Madtom	
		Yellow Bullhead	

In the long term, the lowering of Lake Erie and Lake St. Clair water levels by Plan 25N could impact on spawning grounds, nursery areas, and/or feeding areas within the nearshore zone. In the case of wetlands, lakeward reestablishment could occur, depending on physical constraints; such as, depth contours, shoals, and embayments.

High water levels, at least those held above the long-term mean, tend to produce habitat conditions approaching the hemi-marsh. The regulation plans evaluated limit the occurrence of high water levels. Conversely, the more frequent incidence of low water levels would encourage the development of denser stands of emergent vegetation at the expense of the open-water aquatics zone, a situation less favorable to fish.

High waters would facilitate fish passage between the lake and the wetland and thus permit fish spawning (e.g., northern pike) as well as the wetland rearing of forage fish.

Since a number of the wetlands in the western basin of Lake Erie are diked and regulated, the importance of the unregulated wetlands to the aquatic ecosystem, and to fish directly, is enhanced. Further lowering of the lake's water level could result in an increase in diking to maintain wetland water levels for wildlife management, thereby removing additional wetland areas from potential use by fish.

Plan 25N would extend the duration and amplitude of low levels. This could adversely affect fish by making spawning areas inaccessible, changing the thermal nature of the shallow embayments, and/or changing the quality and quantity of macrophyte communities.

A reduction in the hypolimnion volume would be experienced as a result of the regulation plans (see Water Quality Section of Environmental Effects Appendix). A 1-foot reduction in the Lake Erie central basin hypolimnion thickness could represent as much as a 15 percent reduction in the hypolimnion volume. Thus, the cold water habitat would decrease to the detriment of cold water fish.

Systemic Effects - Lake Ontario:

Plan 25N appears to have little impact on the fish stocks of Lake Ontario. Since the lake is already regulated, the anticipated changes from the basis-of-comparison due to the Lake Erie regulation plans would be small.

The mean levels of Lake Ontario would be raised due to regulation under all Categories. If this increase were to be sustained at abnormally high levels, there could be die-offs of emergent vegetation, which if severe enough could damage fish stocks.

Also, Plan 25N could affect the annual spring rate of increase in Lake Ontario water levels delaying the high period. This type of delay might impact the fish in the nearshore by affecting such things as spawning access and food sources.

Systemic Effects - St. Lawrence River:

The impact of the Lake Erie water level regulation on the St. Lawrence River has received only cursory review. As long as the Ontario outflows are regulated under present Orders of Approval, with no physical modification to the river, little new impact on fish resources would be expected. However, should the Lake Ontario Orders of Approval be modified to accommodate additional outflow from Lake Ontario, adverse impacts on the St. Lawrence River biotic community could be expected.

Structural Effects:

Based upon a review of the Niagara River fish resources and the criteria developed for selecting the least environmentally adverse regulatory structure, site-specific effects of varying severity were identified for each of the regulatory works. These site-specific effects are summarized in Table 68.

Under Category 3, structural changes or remedial measures in the St. Lawrence were considered. It appears that the magnitude of the required dredging would change the physical condition of the river and result in major destruction of aquatic habitat. As input to the United States Winter Navigation Demonstration Program which also discussed similar dredging requirements, several environmental agencies are on record as opposing any major dredging activities in the International Reach of the St. Lawrence River because of the extent and permanence of the habitat destruction.

Structural Effects - Niagara River Regulatory Works:

a. Structure Location/Construction-Related:

The location and construction-related effects of the Niagara River structure of Plan 25N are expected to have adverse effects on fish and fish habitat. Site-specific impacts of construction measures related to Plans 6L and 15S would be minimal. This is due to the location of the construction activities in the Black Rock Lock and Canal, the minimal dredging required and proper disposal of dredged material, and the lack of cofferdamming.

Since the fish populations in the river are restricted to a relatively shallow and narrow area, the proposed bedrock blasting in an area just downstream from the Peace Bridge would result in major fish kills. This could be most devastating to the fish stocks, particularly if the blasting were to occur during spawning and egg incubation periods. This area currently supports smallmouth bass, walleye, and yellow perch. Furthermore, the dredging required for Plan 25N would remove desirable habitat (shallow rifles with isolated deep pools). This would particularly impact the recently developed salmonid fishery (brown trout, rainbow trout, and coho) as a result of the salmonid stocking program.

Table 68 - Niagara River Site Specific Effects

Plan/Stress	Structural	Construction-Related	Operational 1/
6L	Minimal - least of the 3 structures due to nature and location of structure	Minimal due to: - minimal dredging - minor cofferdam - location in Black Rock	Mode of operation required to accommodate boating may have major impacts on Niagara River fisheries; resultant pulsing effect could: - interrupt spawning - induce thermal changes which would affect spawning success among other impacts - increase erosion of shoals and spawning beds resuspended sludge deposits
15S	Minimal due mainly to location	Minor due to location of activities so long as there is proper disposal of excavated material	As Above
25N	Most detrimental due to location and size of structure	Major effects due to: - blasting which will likely result in fish kills and since the fishery in the river is localized the impact would be severe - cofferdaming, altering flow patterns as water is bypassed (could result in bank erosion)	More continuous discharge is less detrimental than pulsing discharge, but the release of water could increase erosion.

1/ It should be noted that the impact due to regulatory works operation may be insignificant when compared to natural surges in Lake Erie outflow as a result of wind setup.

It is anticipated that the cofferdamming required during the construction of the regulatory structure for Plan 25N would cause hydraulic changes in the section of the river adjacent to Fort Erie. These changes could interfere with boat access for fishing and could have serious detrimental effects on the bait fishery along the Canadian shore.

b. Operational:

Operation of any of the proposed regulatory works could adversely affect fish and fish habitat. In the case of 6L and 15S Black Rock Canal alternatives, the mode of operation would produce a pulsing effect that could interrupt spring spawning activity, induce thermal changes adversely affecting spawning success, and resuspend sludge deposits containing substances hazardous to fish. The more continuous discharge of a Niagara River structure would be less detrimental, but the release of water could create downstream erosional effects more severe than for the other structures.

The operation of any one of the regulatory works structures would introduce different hydraulic and environmental conditions in the river. The adaptability of the fish populations to these changes is not known. However review of existing information on the upper Niagara River fisheries, indicates that the fish populations of the river are very well adapted to the present river environment where significant increases in Lake Erie outflow due to wind setup are common. The effects of the sporadic flow increases due to the operation of the regulatory works may be insignificant when compared to this natural phenomena.

Structural Effects - St. Lawrence River Remedial Works:

The St. Lawrence River would see the greatest impact as a result of Category 3 operations through the large amount of dredging required. The dredging would initially destroy fish bottom habitat and benthic organisms which are a food source for many fish species. These organisms may reinvade the bottom over time, however, maintenance dredging could be necessary and thus repeated destruction of the benthos would be expected.

Since the benthic organisms comprise a major food source for many fish species, any effect to the benthos would also impact on the fisheries. Impacts would also be incurred through current changes, restructuring of habitat and temperature changes. Any dredging which would result in removal of food sources or habitat type would be deleterious to those fish species which depend on them.

Destruction of aquatic plants through dredging either directly by removal of the plants or indirectly through excessive turbidity, current or depth would impact the higher life forms. Phytoplankton, periphyton and aquatic macrophyte comprise the primary producers in the river.

The required dredging could alter flow patterns such that damage to shoals and wetlands could occur. These shallow areas are important fish spawning and nursery areas.

6.2.5 Summary

The preceding section presented the evaluation of the regulation plans and associated structural works on water quality, wildlife/wetlands, and fish. The effort was generally based upon existing information and encompasses both quantitative to qualitative analyses. The following summarizes the findings of these analyses.

Water Quality: Lakes Erie and Ontario water quality generally would not be significantly altered by any of the regulation plans. The greatest impacts both adverse and beneficial, would result from Plan 25N. Plans 15S and 6L would have impacts similar to Plan 25N but of a lesser magnitude.

The most significant impact of lowered levels on Lakes Erie and St. Clair would be the reduction in volume in shallow embayments with a small lake/bay interface (Restricted). The resultant dilution capacity loss would enhance the potential for increased embayment pollutant concentration. This condition could become critical in the event of a "slug" pollutant load (e.g., accidental spill, bypass due to equipment malfunction, etc.).

The rate of total phosphorus inputs to Lake Erie could be reduced as a result of a reduction in the rate of shoreline erosion. However, any changes in lakewide phosphorus concentrations would be negligible.

The Lake Erie Central Basin hypolimnion volume loss could amount to as much as 15 percent. The Lake Ontario hypolimnion would not be appreciably affected by any of the regulation plans.

All of the regulation plans would reduce nearshore turbidity on Lake Erie due to reductions in shoreline erosion. However, the projected mean turbidity decreases would be relatively small even under Plan 25N.

Plan 25N would increase the long-term mean Cladophora production in Lake Erie by approximately 2 percent. No appreciable effect on Cladophora production in Lake Ontario is expected under any of the plans.

The regulation plans would not significantly affect the quantity of water available for dilution of wastes emanating from nearshore outfalls. However, some aesthetic drawbacks in the nearshore area may be noticed due to the possible exposure of outfall heads.

Wildlife/Wetlands - Lake Erie, Lake St. Clair, St. Clair River, Detroit River: The lowering of the long-term water levels of Lakes Erie and St. Clair could create large areas of sedge marsh and meadow environments, which would decrease the diversity and density of wetland-dependent wildlife species while enhancing habitat conditions for species not necessarily dependent on wetlands. The landward edges of wetlands exposed and no longer periodically flooded would tend to progress to shrubs and trees if left undisturbed

by human activity. A more probable result would be the encroachment of development into the resultant dry zone along the perimeter of the wetlands.

Plan 25N would be the most damaging plan, resulting in permanent loss of some wetland area especially around the landward edges of existing wetlands. Damages to the vegetative structure of wetlands, resulting from Plan 15S, could also be extensive; however, not as great as Plan 25N. It is felt that Plan 15S, at least for Lake St. Clair, would provide sufficient variability in lake levels to promote species diversity. In Lake Erie, however, there may not be ample variation. Plan 6L would be the least detrimental, however, vegetative zone shifts of a lesser magnitude from open-water aquatics to emergents and sedge/meadow would still occur.

It is not expected that any of the Niagara River regulatory alternatives would greatly affect wildlife.

Wildlife/Wetlands - Lake Ontario: All three proposed regulation plans would produce similar changes in the Lake Ontario water level regime. The impacts of a reduced predominance of sedge/meadow and emergent zones during low and mean water periods and an increased die-back of emergents during increased high water periods are, overall, regarded as indeterminable to slightly beneficial to wetlands and wetland-dependent wildlife.

Fish: It is evident that certain nearshore areas of the Great Lakes provide essential spawning, nursery, and feeding areas for fish stocks. However, without the benefit of site-specific studies to determine how the regulation-induced changes in water levels would impact the fish utilizing these productive nearshore zones, definitive evaluation is not possible. If the habitat of a fish species were modified severely or destroyed through lake level changes, then the fish species would have the potential of being affected to a similar degree. The impact would be felt throughout the system.

It does appear that the construction and operation of the proposed regulatory works could cause adverse environmental effects of fish stocks and fishing activities in the upper Niagara River. However, more detailed information would be required on the biology and population dynamics of the upper Niagara River fish population before the regulatory works could be adequately evaluated.

Habitat alterations in the St. Lawrence River as a result of Category 3 would be very detrimental to the local fish population. The proposed dredging would drastically change portions of the river bottom impacting areas producing food and providing suitable fish habitat.

6.3 Economic Evaluation

6.3.1 Introduction

The 1977 Reference identifies the following interests for which changes in water levels and outflows due to limited regulation of Lake Erie should be investigated: domestic water supply and sanitation, navigation, water supply

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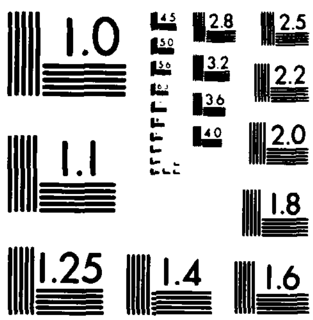

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for power generation and industrial purposes, agriculture, shore property, flood control, fish, wildlife, and recreation. Considering the specific interests affected by lake levels, the interests were grouped into several major classifications. This section presents the probable economic impacts of changes in Great Lakes water levels and outflows due to limited regulation of Lake Erie, and include the following:

1. Coastal Zone, including the effect of variations in water levels and outflows on erosion and inundation of shoreline area (flood control and shore property), and the operation of water intakes (water supply). This also includes the loss of agricultural land through erosion and inundation.

2. Power, including the impact on the power facilities in the St. Marys, Niagara, and St. Lawrence Rivers.

3. Commercial Navigation, including the impact throughout the Great Lakes - St. Lawrence Seaway System.

4. Recreational Beaches and Boating, including the impact on beaches and recreational boating throughout the lower Great Lakes and the St. Lawrence River basin.

Methodologies were developed to express regulation effects in terms of dollars for all of the above interests. Effects on some interests are easily translated into dollar values. Power and commercial navigation are examples where well-established methods are available to translate water level and flow changes. However, with respect to the coastal zone, the translation is more difficult requiring several assumptions within the methodology. With respect to recreational beaches and boating, a field survey was undertaken in the lower lakes in the United States. In summary, the hydrologic effects were translated into dollar values where possible, using the best methodologies that could be devised.

The economic evaluation compares the estimated dollar value, for a 50-year project period, of benefits or losses under the Lake Erie regulation plans to those of the basis-of-comparison. Evaluations were performed for each category. In Categories 1 and 2, all Lake Erie regulation plans were evaluated against the basis-of-comparison, which consisted of Lake Ontario regulated in accordance with Plan 1958-D with discretionary actions. In Category 3, the evaluation was performed using the basis-of-comparison. In addition, Category 3 plans were also evaluated using an adjusted basis-of-comparison which assumed a modified Lake Ontario regulation plan, as well as channel enlargement in the St. Lawrence River to the extent necessary to satisfy the Commission's Orders of Approval throughout the historic period, 1900-1976 (See Sections 4.6.1 and 5.3.1). With these channel enlargements assumed to be in place, the comparison of Lake Erie regulation plans with the adjusted basis-of-comparison provides the impacts due solely to Lake Erie regulation.

An interest rate of 8-1/2 percent was used in determining benefits and costs. This figure is the average of the rates used at the time of regulation plan evaluation by Canadian (10 percent) and U.S. (7.125 percent)

government agencies in the evaluation of water resoruce projects. Moreover, a common dollar value was used for Canadian and United States evaluations. Basic price levels were those of July 1979. In the cost analysis of regulatory works, a project economic life of 50 years was assumed. The probable benefits and losses, and the cost of regulatory works and remedial works are presented in average annual values as well as equivalent present worth.

The following sections present the summary of the economic evaluations of limited regulation of Lake Erie plans.

6.3.2 Coastal Zone

Properties within the coastal zone are subject to two basic types of damage: inundation (flooding) and erosion. It was determined that inundation damages vary with the stormwater level, which was considered to be the sum of the calm level and the wind-generated temporary rise at a specific location. Erosion was assumed to vary directly with the intensity of wave energy reaching the toe of the shoreline bluff.

Water intake facilities are also affected by varying lake levels since the cost of electricity for pumping would increase with decreasing levels.

The methodologies used to evaluate the effect of the regulation plans and the results of these evaluations are described in the following subsections.

Inundation: The methodology used to evaluate inundation differs from previous studies in that stormwater levels were used as an index of inundation damages. For the United States coastal zone, damage data were based on the survey of the 4-year period from Labor Day, 1972 to Labor Day, 1976. Damage data for the Canadian portion of the Great Lakes were based on the Canada-Ontario Great Lakes Shore Damage Survey, covering the period of November 1972 to November 1973. For the Quebec portion of the St. Lawrence River, the 1974 and 1976 inundation events were used as the basis for inundation damage data. Monies spent on construction of new protective works to prevent or alleviate inundation damages were not included in the damage data utilized.

Stormwater stage-damage curves were developed and calibrated based on the recorded stormwater levels of the survey periods and known damages. In developing a relationship between stormwater levels and damages, it was assumed that the still water level and storm setup, acting independently or in combination, are capable of producing damage to the coastal zone. In other words, even at below average lake levels, severe storms can cause inundation damages. At above average lake levels, a small storm can also damage the coastal zone. Damages in any one month may be caused not only by a once-a-month stormwater level, but also by other lower levels during the month. Thus, the stormwater levels are only an index of damage potential. Estimated inundation damages were derived for each month of the year and summed to obtain an annual damage. Average annual damages were based on the annual damages over a period of time.

In evaluating the Quebec portion of the St. Lawrence River, it was necessary to take into account the effects of local inflow and Ottawa River inflow to the Montreal region. The outflow from Lake Ontario under any regulation plan, the local inflow, and the Ottawa River flow were assumed to be independent of one another. Average annual damages were determined based on the combined probability of these events.

There are several major factors which could affect the outcome of the coastal zone evaluation. These factors include future shoreline development, increasing value of already developed coastal zone properties, and assumed wear-off rate. In this study, it was assumed that no additional damage would result from the development of presently undeveloped land due to the institution of coastal zone management in Canada and the United States. Also, it was assumed that there would be no increase in the value of already developed coastal zone properties. The benefits accrued as a result of a reduction in erosion due to lowered mean lake levels were assumed to completely wear-off after 50 years along the Canadian shore, and after 50 to 100 years along the U.S. shore. Within this period, shore processes would adjust to the change due to regulation in mean water level, resulting in a reduction and eventual elimination of the effects of this change.

In order to assess the sensitivity of these factors, different assumptions were made. For example, increased shoreline development and property value of the United States coastal zone was considered. Similar assumptions, however, were not made of the Canadian coastal zone because existing coastal zone management policies were considered effective in preventing development.

Erosion: The evaluation of effects of regulation plans on coastal zone property was based on erosion damage to structures and loss of land through erosion. The methodology used to evaluate erosion damages utilized a "wave energy" approach in the development of stage-damage curves. Wave energy was considered to be the main factor in causing coastal zone damage. Using the wave climate, mean beach slope and the elevation of the bluff toe above a reference level, an index of damage was determined. This index, computed for each reach, was used to convert stage-energy curves to stage-damage curves.

For the United States, the erosion damages utilized were based on the same damage survey as the inundation damages. For the Canadian portion of the Great Lakes, potential future damages were based upon historic erosion rates and shore property values.

Since there would be an increase in the frequency of occurrence of high flows in the St. Lawrence River to a varying degree under all regulation plans, there would be an increase in erosion damages somewhat reducing the overall benefits to the coastal zone interest. However, there were insufficient data to quantitatively evaluate the impact of regulation plans on these damages.

Sensitivity analyses similar to those conducted for inundation were repeated for erosion.

Water Intakes: Many communities and industries along the shoreline of the Great Lakes and their connecting channels have water intakes. A survey of these water intake facilities was carried out in the International Great Lakes Levels Board Study. The same methodology to evaluate the impacts of changing water levels was adopted for this study. The methodology compared pumping costs for water levels under the basis-of-comparison conditions and under limited regulation of Lake Erie conditions. The difference in pumping costs between the two conditions represents a benefit or loss.

Evaluation of Regulation Plans - Plan 25N: The evaluation of the effects of Plans 25N on erosion, inundation, and water intakes pumping is summarized in Table 69.

Compared to the basis-of-comparison, all lakes upstream of Lake Ontario would expect benefits under Plan 25N as a result of reduction in erosion. Lake Erie, which would be most affected by the limited regulation, would expect average annual benefits of about $1,571,000 to the United States coastal zone, and about $76,000 to the Canadian coastal zone. Under Category 1, Lake Ontario would experience average annual losses of about $81,000 and $3,000 to the United States and Canadian coastal zones, respectively. Total average annual benefits for Category 1 erosion would amount to about $2,342,000.

Under Category 2 where Lake Ontario Plan 1958-D would be modified, Lake Ontario would suffer increased erosion damages. Since the mean water level would be raised. The average annual losses to the United States portion of Lake Ontario would be about $206,000. The Canadian portion of Lake Ontario would have erosion losses of about $12,000.

Under Category 3, reduction in average annual erosion damages on Lake Ontario would be about $49,000 when compared to the basis-of-comparison, or $82,000 when compared to the adjusted basis-of-comparison.

All lakes upstream of Lake Ontario would experience a reduction in inundation damages. Lake Erie would have the greatest reduction with an average annual benefit of about $1,761,000 for the United States portion and $231,000 for the Canadian portion. The largest Canadian benefit would be on Lake St. Clair, averaging about $319,000 per year. Under Category 1, Lake Ontario would experience an average annual loss of about $50,000 and $13,000 to the United States and Canadian coastal zone, respectively. The total average annual benefits from reduced inundation for Plan 25N under Category 1 would amount to about $3,135,000. Under Category 2, Lake Ontario inundation losses would increase slightly to about $72,000 per year, while downstream losses in the Quebec portion of the St. Lawrence River would be increased to about $86,000 per year.

Under Category 3, reduction in average annual inundation damages on Lake Ontario would be about $253,000 when compared to the basis-of-comparison, or $166,000 when compared with the adjusted basis-of-comparison. The inundation damages on the St. Lawrence River would account for much of the damages.

Table 69 - Summary of Economic Evaluations for Coastal Zone Interests - Plan 25N

Lake/River		Average Annual Benefits ($000, July 1979 Price Level)				Present Value of Benefits ($000,000)
Lake/River		Erosion	Inundation	Water Intakes	Total	Total
Superior	US	+ 25	+ 39	- 1	+ 63	+ 0.73
	Can.	NE	NE	- 2	- 2	- 0.02
Michigan	US	+453	+ 177	- 65	+565	+ 6.54
Huron	US	+170	+ 235	A	+405	+ 4.68
	Can.	+ 23	+ 41	- 31	+ 33	+ 0.38
St. Clair	US	+ 86	+ 406	0	+492	+ 5.69
	Can.	+ 22	+ 319	0	+341	+ 3.94
Erie	US	+1,571	+1,761	-159	+3,173	+36.70
	Can.	+ 76	+ 231	- 48	+259	+ 3.00
Ontario	US	- 81	- 50	0	-131	- 1.51
(Cat. 1)	Can.	- 3	- 13	0	- 16	- 0.19
St. Law. (Cat. 1)	Can.	NE	- 11	NE	- 11	- 0.13
Total (Cat. 1)		+2,342	+3,135	- 306	+5,171	+59.81
Ontario	US	-206	- 58	+ 2	-262	- 3.03
(Cat. 2)	Can.	- 12	- 14	+ 28	+ 2	+ 0.02
St. Law. (Cat. 2)	Can.	NE	- 86	NE	- 86	- 1.00
Total (Cat. 2)		+2,208	+3,051	- 276	+4,983	+57.63
Against Basis-of-Comparison						
Ontario	US	- 48	+ 15	+ 1	- 32	- 0.37
(Cat. 3)	Can.	- 1	+ 11	+ 19	+ 29	+ 0.33
St. Law.	Can.	NE	-279	NE	-279	- 3.23
Total (Cat. 3)		+2,377	+2,956	- 286	+5,047	+58.37
Against Adjusted Basis-of-Comparison						
Ontario	US	- 73	- 31	+ 1	-103	- 1.19
(Cat. 3)	Can.	- 9	- 9	+ 13	- 5	- 0.06
St. Law.	Can.	NE	-126	NE	-126	- 1.46
Total (Cat. 3)		+2,344	+3,043	- 292	+5,095	+58.93

A Included in Lake Michigan.

NE Not Evaluated. The inclusion of these evaluations would not significantly affect the results.

Except on Lake Ontario there would be a minor increase in pumping costs. System-wide, the average annual losses for Category 1 would be about $306,000, with the largest portion occurring on Lake Erie. Under Category 2, Lake Ontario would have a slight benefit of about $30,000 per year, with system-wide losses of $276,000 per year.

Under Category 3, the benefit on Lake Ontario would increase to $20,000 per year when compared to the basis-of-comparison or $14,000 when compared to the adjusted basis-of-comparison.

In summary, Plan 25N under Category 1 would bring about an average annual benefit to the system-wide coastal zone of about $5,171,000. Reduction in erosion and inundation accounts for much of the benefits. Under Category 2, Plan 25N would decrease the system-wide coastal zone benefits to about $4,983,000. Benefits under Category 3 would not differ much from those of either Category 1 or 2, regardless of the base case used in the evaluation.

The cumulative result of the sensitivity analyses considering alternate assumptions was a range, from 54 percent to 158 percnet, of the system-wide benefits determined for Category 2. A similar range would occur for the other categories.

Evaluation of Regulation Plans - Plan 15S:

The evaluation of average annual benefits/losses on erosion, inundation, and water intakes pumping is summarized in Table 70. Under Category 1, the system-wide average annual erosion benefits for Plan 15S would be about $1,031,000. Lake Erie would obtain the greatest benefit, with erosion reduced an average of $798,000 per year. Lake Ontario erosion damages would increase by about $90,000 per year.

Under Category 2, erosion on Lake Ontario would increase somewhat from Category 1, with a subsequent lowering of system-wide benefits to about $959,000 per year.

For Category 3, higher benefits due to reduced erosion as compared to either the basis-of-comparison or adjusted basis-of-comparison would occur on Lake Ontario, which would result in system-wide reduced erosion benefits of $1,097,000 or $1,065,000 per year, respectively.

All lakes upstream of Lake Ontario would experience a reduction in inundation damage. On Lake Erie, annual inundation damages would be reduced by about $942,000. Annual inundation damages on Lake St. Clair would be reduced by about $395,000. Lake Ontario's annual loss would be about $36,000. Downstream on the St. Lawrence River, annual losses would be about $44,000 for Category 1 regulation. System-wide, the annual benefits due to decreased inundation that accrue to Plan 15S under Category 1, would be about $1,465,000.

Under Category 2, Lake Ontario would not experience as great a loss as under Category 1, but downstream the losses would be increased. System-wide,

Table 70 - Summary of Economic Evaluations for Coastal Zone Interests - Plan 15S

Lake/River	Average Annual Benefits ($000, July 1979 Price Level) Erosion	Inundation	Water Intakes	Total	Present Value of Benefits ($000,000) Total
Superior US	+ 10	+ 14	0	+ 24	+ 0.28
Can.	NE	NE	- 1	- 1	- 0.01
Michigan US	+183	+ 74	- 26	+231	+ 2.67
Huron US	+ 71	+100	A	+171	+ 1.98
Can.	+ 9	+ 20	- 12	+ 17	+ 0.20
St. Clair US	+ 40	+208	0	+248	+ 2.87
Can.	+ 10	+187	0	+197	+ 2.27
Erie US	+763	+815	- 60	+1,518	+17.56
Can.	+ 35	+127	- 19	+143	+ 1.65
Ontario US	- 85	- 29	0	-114	- 1.32
(Cat. 1) Can.	- 5	- 7	+ 6	- 6	- 0.07
St. Law. Can. (Cat. 1)	NE	- 44	NE	- 44	- 0.51
Total (Cat. 1)	+1,031	+1,465	- 112	+2,384	+27.57
Ontario US	-154	- 28	+ 2	-180	- 2.08
(Cat. 2) Can.	- 8	- 4	+ 22	+ 10	+ 0.12
St. Law. Can. (Cat. 2)	NE	- 80	NE	- 80	- 0.93
Total (Cat. 2)	+ 959	+1,433	- 94	+2,298	+26.59
Against Basis-of-Comparison					
Ontario US	- 24	+ 37	+ 1	+ 14	+ 0.16
(Cat. 3) Can.	0	+ 17	+ 13	+ 30	+ 0.34
St. Law. Can.	NE	-291	NE	-291	- 3.36
Total (Cat. 3)	+1,097	+1,308	- 104	+2,301	+26.61
Against Adjusted Basis-of-Comparison					
Ontario US	- 49	- 9	+ 1	- 57	- 0.66
(Cat. 3) Can.	- 7	- 3	+ 6	- 4	- 0.05
St. Law. Can.	NE	-138	NE	-138	- 1.60
Total (Cat. 3)	+1,065	+1,395	- 111	+2,349	+27.16

A Included in Lake Michigan.

NE Not Evaluated. The inclusion of these evaluations would not significantly affect the results.

Plan 15S under Category 2 would bring about an inundation benefit of about $1,433,000 annually.

A benefit due to reduced inundation on Lake Ontario would occur for Plan 15S under Category 3, but this would be more than offset by increased losses on the St. Lawrence River. Plan 15S under Category 3 would bring about inundation benefits system-wide of about $1,308,000 per year when compared to the basis-of-comparison or $1,395,000 per year when compared to the adjusted basis-of-comparison.

Water intake pumping costs would be relatively unaffected by Plan 15S. Minor losses would occur on Lakes Michigan-Huron and Erie. Pumping costs would increase about $112,000 per year for Plan 15S under Category 1, $94,000 per year under Category 2, and $104,000 and $111,000 per year under Category 3 compared to the basis-of-comparison and adjusted basis-of-comparison, respectively.

In summary, Plan 15S under Category 1 would bring about an average annual benefit to the coastal zone of about $2,384,000; with the major portion of the benefits on Lakes Erie and St. Clair, and a slight loss to Lake Ontario and downstream. Plan 15S under Category 2, would result in system-wide benefits of about $2,298,000 per year. Benefits under Category 3 would not differ much from those of either Category 1 or 2, regardless of the base case used in the evaluation.

The cumulative results of the sensitivity analyses which considered alternate assumptions was a range, from system-wide benefits 55 percent to 159 percent, of the system-wide benefits determined for Category 2. A similar range would occur for the other categories.

Evaluation of Regulation Plans - Plan 6L:

Plan 6L would utilize the modified Black Rock Canal Navigation Lock to discharge additional Lake Erie outflow. The capacity of the modified lock would not be as large as that of the Squaw Island control structure required for Plan 15S. Therefore, the impacts of Plan 6L on the water levels and flows would be smaller than those of Plan 15S. As a result, the expected benefits and losses to coastal zone interests, with respect to erosion, inundation, and water intakes, would likewise be smaller than those of Plan 15S. As a result, the expected benefits and losses to coastal zone interests, with respect to erosion, inundation, and water intakes, would likewise be smaller than Plan 15S. Table 71 is a summary of the expected impacts for Plan 6L.

The results of the sensitivity analyses which considered alternate assumptions showed system-wide benefits ranging from 58 percent to 157 percent of the benefits determined for Category 2. A similar range would occur for the other categories.

Table 71 - Summary of Economic Evaluations for Coastal Zone Interests - Plan 6L

Lake/River		Average Annual Benefits ($000, July 1979 Price Level) Erosion	Inundation	Water Intakes	Total	Present Value of Benefits ($000,000) Total
Superior	US	+ 3	+ 4	0	+ 7	+ 0.08
	Can.	NE	NE	0	0	0.00
Michigan	US	+ 69	+ 29	- 9	+ 89	+ 1.03
Huron	US	+ 27	+ 40	A	+ 67	+ 0.77
	Can.	+ 4	+ 8	- 4	+ 8	+ 0.09
St. Clair	US	+ 15	+ 85	0	+100	+ 1.16
	Can.	+ 4	+ 82	0	+ 86	+ 0.99
Erie	US	+295	+332	- 23	+604	+ 6.99
	Can.	+ 14	+ 56	- 7	+ 63	+ 0.73
Ontario	US	- 23	- 7	+ 1	- 29	- 0.33
(Cat. 1)	Can.	+ 3	+ 3	+ 3	+ 9	+ 0.10
St. Law. (Cat. 1)	Can.	NE	+ 18	NE	+ 18	+ 0.21
Total (Cat. 1)		+ 411	+ 650	- 39	+1,022	+11.82
Ontario	US	- 82	- 9	+ 1	- 90	- 1.04
(Cat. 2)	Can.	+ 1	+ 3	+ 16	+ 20	+ 0.23
St. Law. (Cat. 2)	Can.	NE	+ 3	NE	+ 3	+ 0.04
Total (Cat. 2)		+ 350	+ 633	- 26	+ 957	+11.07
Against Basis-of-Comparison						
Ontario	US	+ 12	+ 42	0	+ 54	+ 0.62
(Cat. 3)	Can.	+ 6	+ 21	+ 9	+ 36	+ 0.42
St. Law.	Can.	NE	-162	NE	-162	- 1.87
Total (Cat. 3)		+ 449	+ 537	- 34	+ 952	+11.01
Against Adjusted Basis-of-Comparison						
Ontario	US	- 13	- 4	0	- 17	- 0.20
(Cat. 3)	Can.	- 1	+ 1	+ 3	+ 3	+ 0.04
St. Law.	Can.	NE	- 9	NE	- 9	- 0.10
Total (Cat. 3)		+ 417	+ 624	- 40	+1,001	+11.58

A Included in Lake Michigan.
NE Not Evaluated. The inclusion of these evaluations would not significantly affect the results.

6.3.3 Power

The effect of limited regulation of Lake Erie on hydropower installations was determined by comparing the power that could be generated under the basis-of-comparison with the power that could be generated under each of the regulation plans, and evaluating the difference in terms of the cost of replacement power.

The existing hydroelectric installations on the outlet rivers of the Great Lakes that could be affected by changes in the water level and flow regime of the system have a total installed capacity of just over 8,000,000 kw. These plants and their major operating features are described in Section 2.6. It is assumed for these studies that there will be no change in the installed capacity over the 50-year study period, 1985 through 2034.

Determination of Power Generation:

Power generation in terms of peak load meeting capability and energy outputs from the existing power installations on the Great Lakes depends on the net head and flows available. The methodology for determining the peak and energy output is described in detail in Appendix E, and is essentially the same as that used for the International Great Lakes Levels Board's Report dated December 1973. Computer models that were developed for each plant or group of plants were updated as required.

The model input is the 77-year regime of monthly mean lake levels and outflows, for the basis-of-comparison and each regulation plan. Except for the United States Niagara plants, for each month of the period 1900 throughout 1976 (77 years), the computer programs determine the amount of water available to each plant, the corresponding head, the average monthly energy output, and the peak output. From this, the average annual energy and peak load meeting capability is calculated. In the case of the U.S. Niagara plants, the gain or loss in energy and peak output is derived from an analysis of duration listings of monthly Lake Erie outflows.

A significant change was required in the St. Lawrence Project program in order to compute the power outputs under Category 3. Under this category, it was necessary to provide additional channel capacity in both the Canadian and International reaches of the St. Lawrence River. For the Moses-Saunders Plants power evaluation, revised channel losses between Lake Ontario and the power dam were required.

On St. Marys River, the power output from the Canadian plant is based on the renovated Great Lakes Power Company plant which will be operational at the end of 1982. The methodology was developed by Ontario Hydro in cooperation with Great Lakes Power Corporation.

Ice conditions limit the flow at the time that the Hydro Quebec system experiences peak load; therefore, no peak capacity benefits are expected on this system.

Determination of Benefits of Losses: The average annual energy and load meeting capability for each plant or group of plants as determined for the basis-of-comparison is subtracted from the corresponding values for each regulation plan to determine the benefit or loss. Although this methodology may appear to be obvious, it is mentioned here in order to clarify that the economic evaluation was based on the gain or loss in power and not on the total generation.

Determination of Unit Costs: To evaluate the various plans, estimates were prepared of the annual value of replacement peak and energy over the study period. These costs assumed a discount rate of 8.5 percent, a project economic life of 50 years (1985 to 2034) and July 1979 price levels.

In the case of Ontario Hydro and Hydro Quebec, the system values included inflation and these were first converted to 1979 dollars by a discounting factor.

The Ontario system values are based on an anticipated mixture of coal and nuclear replacement power. The Quebec values assume hydroelectric replacement to 1995 and nuclear thereafter. The New York State values are based on oil as the replacement fuel and assume a 5 percent price increase compounded annually from 1979 through 2005, and then no further increase. For the Upper Michigan plants on the St. Marys River, the present costs were assumed to occur throughout the 50-year period.

For each system, the 50 years of annual costs in real 1979 dollars were discounted at 8.5 percent to 1985 values to arrive at the total present worth from which the average annual value was determined. The average annual replacement costs of energy and capacity for each system is shown on the following table:

Table 72 - Average Annual Cost of Replacement Power, 1985-2034 (1979 Dollars)

System	Quebec	Ontario Day	Ontario Night	New York	U.S. Plants Upper Michigan
Energy mills/kwh	7.6	17.24	12.12	110.6	3.36
Capacity $/kw		33.08		70	28.33

Evaluation of Regulation Plans: The results of the evaluation are shown on Tables 73 through 78. Table 73 shows the difference in average annual energy production and peak load meeting capability for Plans 6L, 15S, and 25N compared to the basis-of-comparison for each system under Category 1. Tables 74 and 75 show the power differences under Categories 2 and 3. Tables 76, 77, and 78 show the average annual value of peak and energy and present worth values under these three categories.

Table 73 - Power Evaluation - Category 1

Difference in Average Annual Energy Production
and
Peak Load Meeting Capability

	Difference from Basis-of-Comparison					
	Average Annual Energy - (Gwh)			Peak Capacity - (Mw)		
	6L	15S	25N	6L	15S	25N
Ontario						
St. Marys	+0.3	+1.4	+2.2			
Niagara	-23.3	-68.3	-61.1			
St. Lawrence	-1.1	+0.5	-5.1			
Total	-24.1	-66.4	-64.0	+0.8	+0.2	-0.8
Quebec						
Beauharnois and Cedars	-2.6	-5.2	- 7.3			
Total Canada	-26.7	-71.6	-71.3	+0.8	+0.2	-0.8
New York State						
Niagara	-1.1	-2.5	-0.7	-0.4	-1.3	-9.0
St. Lawrence	-1.1	+0.5	-5.1	+0.2	+0.2	-1.4
Total	-2.2	-2.0	-5.8	-0.2	-1.1	-10.4
Upper Michigan	+0.2	+1.7	+2.0	0	0	+0.1
Total U.S.	-2.0	-0.3	-3.8	-0.2	-1.1	-10.3
Total U.S. and Canada	-28.7	-71.9	-75.1	+0.6	-0.9	-11.1

Table 74 - Power Evaluation - Category 2

Difference in Average Annual Energy Production
and
Peak Load Meeting Capability

	Difference from Basis-of-Comparison					
	Average Annual Energy - (Gwh)			Peak Capacity - (Mw)		
	6L	15S	25N	6L	15S	25N
Ontario						
St. Marys	+0.3	+1.4	+2.2			
Niagara	-23.8	-69.2	-63.0			
St. Lawrence	+3.8	+5.8	+3.0			
Total	-19.7	-62.0	-57.8	-2.4	-2.9	-4.5
Quebec						
Beauharnois and Cedars	+1.2	-2.3	-4.7	___	___	___
Total Canada	-18.5	-64.3	-62.5	-2.4	-2.9	-4.5
New York State						
Niagara	-1.1	-2.5	-0.7	-0.4	-1.3	-9.0
St. Lawrence	+3.8	+5.8	+3.0	+0.2	+0.1	-0.9
Total	+2.7	+3.3	+2.3	-0.2	-1.2	- 9.9
Upper Michigan	+0.2	+1.7	+2.0	0	0	+0.1
Total U.S.	+2.9	+5.0	+4.3	-0.2	-1.2	-9.8
Total U.S. and Canada	-15.6	-59.3	-58.2	-2.6	-4.1	-14.3

Table 75 - Power Evaluation - Category 3

Difference in Average Annual Energy Production
and
Peak Load Meeting Capability

	Difference from Basis-of-Comparison					
	Average Annual Energy - (Gwh)			Peak Capacity - (Mw)		
	6L	15S	25N	6L	15S	25N
Ontario						
St. Marys	+0.3	+1.4	+2.2			
Niagara	-23.0	-67.7	-63.1			
St. Lawrence	+ 4.0	+ 8.8	+ 2.3			
Total	-18.7	-57.5	-58.6	-5.6	-3.1	-2.4
Quebec						
Beauharnois and Cedars	-9.3	-14.8	-17.5	—	—	—
Total Canada	-28.0	-72.3	-76.1	-5.6	-3.1	-2.4
New York State						
Niagara	-1.1	-2.5	-0.7	-0.4	-1.3	-9.0
St. Lawrence	+ 4.0	+ 8.8	+ 2.3	+0.4	+0.8	-0.6
Total	+ 2.9	+ 6.3	+ 1.6	0	-0.5	-9.6
Upper Michigan	+0.2	+1.7	+2.0	0	0	+0.1
Total	+ 3.1	+ 8.0	+ 3.6	0	-0.5	-9.5
Total U.S. and Canada	-24.9	-64.3	-72.5	-5.6	-3.5	-11.9

Table 75 (Cont'd) - Power Evaluation - Category 3

Difference in Average Annual Energy Production
and
Peak Load Meeting Capability

	Difference from Adjusted Basis-of-Comparison					
	Average Annual Energy - (Gwh)			Peak Capacity - (Mw)		
	6L	15S	25N	6L	15S	25N
Ontario						
St. Marys	+0.3	+1.4	+2.2			
Niagara	-23.0	-67.7	-63.1			
St. Lawrence	- 0.1	+ 4.7	- 1.8			
Total	-22.8	-61.6	-62.7	-2.7	-0.2	+0.4
Quebec						
Beauharnois and Cedars	-2.1	- 7.7	-10.3	___	___	___
Total Canada	-24.9	-69.3	-73.0	-2.7	-0.2	+0.4
New York State						
Niagara	-1.1	-2.5	-0.7	-0.4	-1.3	-9.0
St. Lawrence	-0.1	+ 4.7	- 1.8	0	+0.4	-1.0
Total	- 1.2	+ 2.2	- 2.5	-0.4	-0.9	-10.0
Upper Michigan	+0.2	+1.7	+2.0	0	0	+0.1
Total	- 1.0	+ 8.9	- 0.5	-0.4	-0.9	-9.9
Total U.S. and Canada	-25.9	-65.4	-73.5	-3.1	-1.1	- 9.5

Table 76 - Power Evaluation - Category 1

Annual Amortized and Present Worth Values of Difference
(from Basis-of-Comparison)
in
Average Annual Energy and Peak Load Meeting Capability

	Annual Amortized Value ($1000s)									Present Worth of Total ($1000s)		
	Energy			Peak			Total					
	6L	15S	25N	6L	15S	25N	6L	15S	25N	6L	15S	25N
Ontario												
St. Marys	+5	+22	+34									
Niagara	-459	-1,277	-964									
St. Lawrence	-19	+3	-105									
Total	-473	-1,252	-1,035	+25	+7	-26	-448	-1,245	-1,061	-5,181	-14,399	-12,271
Quebec												
Beauharnois and Cedars	-20	-39	-55	-	-	-	-20	-39	-55	-231	-451	-636
Total Canada	-493	-1,291	-1,090	+25	+7	-26	-468	-1,284	-1,116	-5,412	-14,850	-12,907
New York State												
Niagara	-122	-276	-77	-28	-91	-630						
St. Lawrence	-122	+55	-564	+14	+14	-98						
Total	-244	-221	-641	-14	-77	-728	-258	-298	-1,369	-2,984	-3,447	-15,833
Upper Michigan	+1	+6	+7	0	+1	+2	+1	+7	+9	+12	+81	+104
Total U.S.	-243	-215	-634	-14	-76	-726	-257	-291	-1,360	-2,972	-3,366	-15,729
Total Canada and U.S.	-736	-1,506	-1,724	+11	-69	-752	-725	-1,575	-2,476	-8,384	-18,216	-28,636

Table 77 - Power Evaluation - Category 2

Annual Amortized and Present Worth Values of Difference
(from Basis-of-Comparison)
in
Average Annual Energy and Peak Load Meeting Capability

	Annual Amortized Value ($1000s)									Present Worth of Total ($1000s)		
	Energy			Peak			Total					
	6L	15S	25N	6L	15S	25N	6L	15S	25N	6L	15S	25N
Ontario												
St. Marys	+5	+22	+34									
Niagara	-466	-1,290	-993									
St. Lawrence	+54	+81	+16									
Total	-407	-1,187	-943	-78	-97	-147	-485	-1,284	-1,090	-5,609	-14,850	-12,606
Quebec												
Beauharnois and Cedars	+9	-17	-36	—	—	—	+9	-17	-36	+104	-197	-416
Total Canada	-398	-1,204	-979	-78	-97	-147	-476	-1,301	-1,126	-5,505	-15,047	-13,022
New York State												
Niagara	-122	-276	-77	-28	-91	-630						
St. Lawrence	+420	+641	+332	+14	+7	-63						
Total	+298	+365	+255	-14	-84	-693	+284	+281	-438	+3,285	+3,250	-5,066
Upper Michigan	+1	+6	+7	0	+1	+2	+1	+7	+9	+12	+81	+104
Total U.S.	+299	+371	+262	-14	-83	-691	+285	+288	-429	+3,297	+3,331	-4,962
Total Canada and U.S.	-99	-833	-717	-92	-180	-838	-191	-1,013	-1,555	-2,208	-11,716	-17,984

Table 78 - Power Evaluation - Category 3

Annual Amortized and Present Worth Values of Difference
(from Basis-of-Comparison)
in
Average Annual Energy and Peak Load Meeting Capability

	Annual Amortized Value ($1000s)									Present Worth of Total ($1000s)		
	Energy			Peak			Total					
	6L	15S	25N	6L	15S	25N	6L	15S	25N	6L	15S	25N
Ontario												
St. Marys	+5	+22	+34									
Niagara	-454	-1,268	-995									
St. Lawrence	+62	+135	+11									
Total	-387	-1,111	-950	-184	-101	-80	-571	-1,212	-1,030	-6,604	-14,017	-11,912
Quebec												
Beauharnois and Cedars	-70	-112	-132	—	—	—	-70	-112	-132	-810	-1,295	-1,527
Total Canada	-457	-1,223	-1,082	-184	-101	-80	-641	-1,324	-1,162	-7,414	-15,312	-13,439
New York State												
Niagara	-122	-276	-77	-28	-91	-630						
St. Lawrence	+442	+973	+254	+29	+58	-41	—	—	—	—	—	—
Total	+320	+697	+177	+1	-33	-671	+321	+664	-494	+3,712	+7,680	-5,713
Upper Michigan	+1	+6	+7	0	+1	+2	+1	+7	+9	+12	+81	+104
Total U.S.	+321	+703	+184	+1	-32	-669	+322	+671	-485	+3,724	+7,761	-5,609
Total Canada and U.S.	-136	-520	-898	-183	-133	-749	-319	-653	-1,647	-3,690	-7,551	-19,048

Table 77 - Power Evaluation - Category 2

Annual Amortized and Present Worth Values of Difference
(from Basis-of-Comparison)
in
Average Annual Energy and Peak Load Meeting Capability

	Annual Amortized Value ($1000s)									Present Worth of Total ($1000s)		
	Energy			Peak			Total					
	6L	15S	25N	6L	15S	25N	6L	15S	25N	6L	15S	25N
Ontario												
St. Marys	+5	+22	+34									
Niagara	-466	-1,290	-993									
St. Lawrence	+54	+81	+16									
Total	-407	-1,187	-943	-78	-97	-147	-485	-1,284	-1,090	-5,609	-14,850	-12,606
Quebec												
Beauharnois and Cedars	+9	-17	-36	—	—	—	+9	-17	-36	+104	-197	-416
Total Canada	-398	-1,204	-979	-78	-97	-147	-476	-1,301	-1,126	-5,505	-15,047	-13,022
New York State												
Niagara	-122	-276	-77	-28	-91	-630						
St. Lawrence	+420	+641	+332	+14	+7	-63						
Total	+298	+365	+255	-14	-84	-693	+284	+281	-438	+3,285	+3,250	-5,066
Upper Michigan	+1	+6	+7	0	+1	+2	+1	+7	+9	+12	+81	+104
Total U.S.	+299	+371	+262	-14	-83	-691	+285	+288	-429	+3,297	+3,331	-4,962
Total Canada and U.S.	-99	-833	-717	-92	-180	-838	-191	-1,013	-1,555	-2,208	-11,716	-17,984

Table 78 - Power Evaluation - Category 3

Annual Amortized and Present Worth Values of Difference
(from Basis-of-Comparison)
in
Average Annual Energy and Peak Load Meeting Capability

	Annual Amortized Value ($1000s)									Present Worth of Total ($1000s)		
	Energy			Peak			Total					
	6L	15S	25N	6L	15S	25N	6L	15S	25N	6L	15S	25N
Ontario												
St. Marys	+5	+22	+34									
Niagara	-454	-1,268	-995									
St. Lawrence	+62	+135	+11									
Total	-387	-1,111	-950	-184	-101	-80	-571	-1,212	-1,030	-6,604	-14,017	-11,912
Quebec												
Beauharnois and Cedars	-70	-112	-132				-70	-112	-132	-810	-1,295	-1,527
Total Canada	-457	-1,223	-1,082	-184	-101	-80	-641	-1,324	-1,162	-7,414	-15,312	-13,439
New York State												
Niagara	-122	-276	-77	-28	-91	-630						
St. Lawrence	+442	+973	+254	+29	+58	-41						
Total	+320	+697	+177	+1	-33	-671	+321	+664	-494	+3,712	+7,680	-5,713
Upper Michigan	+1	+6	+7	0	+1	+2	+1	+7	+9	+12	+81	+104
Total U.S.	+321	+703	+184	+1	-32	-669	+322	+671	-485	+3,724	+7,761	-5,609
Total Canada and U.S.	-136	-520	-898	-183	-133	-749	-319	-653	-1,647	-3,690	-7,551	-19,048

Table 78 (Cont'd) - Power Evaluation - Category 3

Annual Amortized and Present Worth Values of Difference
(from Adjusted Basis-of-Comparison)
in
Average Annual Energy and Peak Load Meeting Capability

	Annual Amortized Value ($1000s)									Present Worth of Total ($1000s)		
	Energy			Peak			Total					
	6L	15S	25N	6L	15S	25N	6L	15S	25N	6L	15S	25N
Ontario												
St. Marys	+5	+22	+34									
Niagara	-454	-1,268	-995									
St. Lawrence	-2	+70	-53									
Total	-451	-1,176	-1,014	-89	-6	+15	-540	-1,182	-999	-6,245	-13,671	-11,554
Quebec												
Beauharnois and Cedars	-16	-58	-78	—	—	—	-16	-58	-78	-185	-671	-902
Total Canada	-467	-1,234	-1,092	-89	-6	+15	-556	-1,240	-1,077	-6,430	-14,342	-12,456
New York State												
Niagara	-122	-276	-77	-28	-91	-630						
St. Lawrence	-11	+520	-199	0	+29	-70						
Total	-133	+244	-276	-28	-62	-700	-161	+182	-976	-1,862	+2,104	-11,288
Upper Michigan	+1	+6	+7	0	+1	+2	+1	+7	+9	+12	+81	+104
Total U.S.	-132	+250	-269	-28	-61	-698	-160	+189	-967	+1,850	+2,185	-11,184
Total Canada and U.S.	-599	-984	-1,361	-117	-63	-683	-716	-1,051	-2,044	-8,280	-12,157	-23,640

Under each of the three categories being considered only Lake Ontario is regulated differently. For this reason, only the St. Lawrence River plants show an appreciable change in benefit or losses according to category. The benefits from the St. Marys and Niagara River plants are essentially the same for the three categories.

The major effect of limited regulation of Lake Erie is a significant loss at the Canadian plants on the Niagara River of about 23 Gwh for Plan 6L, 68 Gwh for Plan 15S, and 61 Gwh for Plan 25N. This loss is due to some of the additional water that is discharged from Lake Erie during the high supply period being wasted or used at the Cascade plants which have a lower economy factor (kw/cfs) than the high head Beck plants. The proportionally larger losses for Plans 15S and 6L despite their lower discharge capacities are due to the operating constraints by which virtually all the additional water during the high supply period is discharged during the tourist season nights and non-tourist season when the Niagara Falls flow requirement is 50,000 cfs. Plan 25N, on the other hand, discharges the additional water during the daylight hours of the tourist season as well, when the falls flow requirement is 100,000 cfs.

On the St. Lawrence River the Beauharnois and Cedars plants show losses of up to 7 Gwh for Plan 25N under Category 1. At the Moses-Saunders Plants there would be generally a small loss under Category 1 and a small gain under Category 2 compared to the basis-of-comparison. Category 3 shows benefits at the Moses-Saunders Plant as a result of a decrease in head loss from Lake Ontario to the forebays, due to channel excavations which were considered in Category 3 plans. However, compared to the adjusted basis-of-comparison in which modified Plan 1958-D and channel enlargements were also considered, there would be some losses at the Moses-Saunders Plants.

In terms of annual value, the United States benefits (+) or losses (-) from 6L, 15S, and 25N are -$257,000, -$291,000, and -$1,360,000, respectively for Category 1 and +$285,000, +$288,000, and -$429,000, respectively for Category 2. For Category 3, the United States benefits or losses, when compared to the basis-of-comparison, would be +$322,000, +$671,000, and -$485,000 for Plans 6L, 15S, and 25N, respectively. Compared to the adjusted basis-of-comparison, the benefits or losses would become -$160,000, +$189,000, and -$967,000, respectively. Figures for Canada are also shown in Tables 76, 77, and 78.

It should be pointed out that initially the study results revealed small benefits at the St. Lawrence River generating stations under Category 1. However, examination of long-term (1900-1976) mean outflows for each lake revealed that for all plans and all categories, the outflows were greater than those for the basis-of-comparison by varying amounts up to about 400 cfs. This is due to the gradual reduction in storage on Lake Erie and the Upper Great Lakes caused by limited regulation of Lake Erie. As a result, the outputs from the plants were adjusted to exclude these differences in long-term mean outflow.

6.3.4 Navigation Evaluation

Regulation plans were evaluated to determine to what extent the cost of goods transported in the Great Lakes - St. Lawrence system would be affected for the period 1985 through 2035.

The relationship between lake level and transportation cost is based on the allowable draft of shipping. In the Great Lakes - St. Lawrence River system, allowable draft is limited by the depth of water in the harbours and the connecting channels between the lakes. When the depth in one of these "restricted" parts of the system is altered by a change in lake levels, the allowable draft, and therefore the loading of ships wishing to use that part of the system at that time may be affected. Any change in the loading capacity of ships on a route, results in a change in the number of ship-hours required to move a given volume of goods over that route. A change in the number of ship-hours required, changes the total operating expenses involved, and so changes the total cost of transporting those goods.

This reasoning forms the basis of a detailed calculation procedure which is applied on a monthly basis to each shipping route in the future Great Lakes - St. Lawrence River trades. Annual total transportation costs for the entire system are calculated for each of the three regulation plans, for each forecast year. These are compared with the transportation cost for the basis-of-comparison case. The difference in costs between base case and a regulation plan is the benefit or loss to shipping.

Projections of future bulk waterborne commerce, the character, and composition of the future vessel fleet, vessel traffic patterns, and vessel operating characteristics and costs were developed. The evaluation methodology used in the International Great Lakes Levels Board Study, completed in 1973, was updated and improved to handle additional impact data and criteria. The resulting analysis assesses the impact of lake level regulation on bulk commerce in iron ore, coal, limestone, and grain. This traffic comprises about 85 percent of all Great Lakes traffic and includes all significant present and projected commerce required for assessment.

The assessment methodology is composed primarily of forecasts and projections concerning the operation of the future navigation system. There are many things political that can affect the future operation of the system that cannot be predicted very far in advance. These include wars, major depressions and government transportation policies. To cover the uncertainties in these areas, the following assumptions were made:

1. There will be no wars or national economic depressions during the period of projection;

2. Policies, including those concerning tolls and user charges, will not change to an extent which would seriously unbalance the present relationships between modes of transportation;

3. Except for some new or changed sources and markets for portions of some bulk trades (e.g. western coal), there will be no other radical changes in the sources and markets of the principal commodities moving on the Great Lakes, and therefore, no other major changes in the present general pattern of traffic;

4. The patterns and proportions of utilization of the two national fleets in the lakes bulk trades will remain unchanged;

5. The major physical make-up and operational aspcts of the navigation system, as it presently exists, will remain essentially unchanged for the entire period of projection. That is, there will be no major development or modernization, except the Poe Lock which will be permitted to pass vessels of 1,100 feet-by-105 feet after 1990.

Regarding operation, the following navigation seasons were used for the entire period of projection:

a. Montreal Harbour and below - year round;

b. Lake Ontario and the Montreal-to-Lake Ontario portion of the Seaway - 8.5 months, April 1 to December 15;

c. The Welland Canal and the Upper Lakes - 9 months, April 1 to January 1;

(Further discussions of the physical and operational characteristics of the navigation system used in this study appear in Section 2.7 and Table 13).

6. The Welland Canal will reach capacity in terms of lockages per day, by the early 1990's and the Soo Locks by about 1995.

Estimates of the cost of transportation for each commodity, traffic route, and vessel class were made. For example, the cost of shipping iron ore in class 10 vessels on the Lake Superior (origin) to Lake Erie (destination) route were computed under the basis-of-comparison and under regulation plan conditions. If the cost under regulation plan conditions were higher, then that was considered a loss to navigation.

It is important to note that, in most cases, only a portion of the reduction in Lake Erie levels affects navigation. The depth of navigation channels is measured from low water datum (LWD) on each lake. Since the level of Lake Superior is usually closer to LWD than the other lakes, that lake usually limits the cargo loading capacity of vessels. Thus, Lake Erie levels would need to be reduced to a comparable level before any loss to navigation occurs. On the other hand, when Lake Erie is the controlling lake under basis-of-comparison conditions, then all of the reduction in Lake Erie levels affects navigation. The regulation plans considered in this study would result in lower Lake Erie levels and therefore increase the number of occasions when Lake Erie controls. Table 79 shows the effect of lower Lake Erie levels in terms of levels on the Superior-Michigan Huron-Erie (S-MH-E) and Michigan Huron-Erie (MH-E) routes.

Table 79 - Percent of Time that Each Lake Controls the Depth Available to Commercial Navigation (April -December)

Plan	Route S-MH-E S			MH-E MH	
	S	MH	E	MH	E
Basis-of-Comparison	89.7	9.7	0.6	91.2	8.8
Plan 6L	89.5	9.9	0.6	89.3	10.7
Plan 15S	88.1	11.1	0.8	84.7	15.3
Plan 25N	82.2	13.3	4.5	67.9	32.1

Transportation Cost: The annual transportation cost for a given regime of lake levels was based on parameters described in the following paragraphs.

Transportation Cost - Traffic Projections: Bulk commerce in iron ore, coal, limestone, and grain were projected for the years 1985, 2000, and 2035. These four bulk commodities comprise about 85 percent of total Great Lakes traffic and include all significant present and future traffic required for assessment. The remaining 15 percent, not evaluated, is composed of a number of cargoes including petroleum products, newsprint, and many other goods which either are carried by smaller, lesser draft vessels which cannot take full advantage of available water depths, or are shipped in quantities too small to warrant analysis in this study.

The 15 percent also includes overseas general cargo. These trades employ specialized lake-ocean carriers. Although, overseas cargo is of high value, traffic to and from the Great Lake must transit the 27-foot St. Lawrence Seaway. Since the Seaway restricts draft to 26 feet, this traffic cannot take advantage of water depths greater than about 27.5 feet (allowing 1.5 feet for underkeel clearance) in the harbours on the lakes. Since lake levels are such that harbour depths are rarely below this depth, overseas, general cargo traffic would not be affected significantly by a small change in the levels regime. In addition, while on the lakes many of these vessels call at several ports and therefore often do not travel fully loaded, and thus do not normally take full advantage of water depths available. For these reasons, overseas general cargo traffic is excluded from this analysis.

Transportation Cost - United States and Canadian Vessel Fleets: The size, composition, and operating characteristics of the vessel fleet, transporting the bulk commodities, were also projected for years 1985, 2000, and 2035. The years since World War II have seen the collapse of the historic Great Lakes package fleet trade; the demise of passenger ships and the retirement of hundreds of small "canallers," uneconomical and incapable of survival in an era of mass production and mass movement. Since the opening of the Poe Lock in 1969, many of the older, smaller lakers were replaced by larger class 10 (1,000-foot) vessels. The Great Lakes fleet is

now characterized by fewer, but larger vessels. Projected traffic was assigned to the various classes of vessels in the fleet according to historic patterns and future fleet composition and carrying capacity.

Transportation Cost - Traffic Routes: Projected bulk traffic was assigned to traffic routes by lake of origin and destination. The traffic patterns were determined by combining historic patterns with new and future movements such as the recent western coal movement from Lake Superior to Lakes Huron and Erie.

Transportation Cost - Monthly Mean Lake Level: The regime of lake levels under the basis-of-comparison and regulation plan conditions were compared, using monthly mean lake levels over the period of record.

Transportation Cost - Vessel Capacity and Immersion Factor: The change in cargo carrying capacity was determined by use of maximum vessel capacity and the cargo capacity represented by a known change in vessel draft (immersion factor), expressed in tons per foot.

Transportation Cost - Vessel Trips Required: The trips required to carry the projected commerce were computed using the distribution of traffic by vessel class and route, and the capacity of the ship under prevailing lake level conditions. If the lake levels were lowered, more trips would be required to carry a given number of tons.

Transportation Cost - Trip Time Charged to Commodity: Round trip times for each route and commodity were determined from the trip distance, average vessel speed, and loading and unloading time.

The computation of transportation cost must recognize that many vessels are not dedicated to the movement of one commodity exclusively; and therefore, trip itineraries are varied, and some portion of a round trip is chargeable to more than one commodity. For example, a ship may carry iron ore from Lake Superior to Lake Michigan, then travel empty to Toledo, Ohio, for a load of coal to some other port on Lake Erie, then empty to Escanaba, Michigan, for another load of ore bound for southern Lake Michigan, then empty back to Lake Superior for another load of ore. Although the trip itineraries are varied, it is possible by examining several hundred trips for a season, to determine the percent of trip time chargeable to each commodity.

Transportation Cost - Vessel Hourly Operating Cost: Vessel hourly operating costs were determined using recent data from the Maritime Administration in the U. S. and the St. Lawrence Seaway Authority in Canada. In view of the recent rapid rise in the cost of fuel, the fuel portion of daily operating costs was estimated to rise 5 percent faster than inflation for the first 20 years of project life (1985-2005).

Evaluation of Regulation Plans: The evaluation results are shown in Tables 80, 81, and 82. The annual cost of transportation is shown under basis-of-comparison conditions or adjusted basis-of-comparison. The losses shown for the three plans represent the added costs of additional trips to carry the tonnage lost because of lower lake levels. While the economic

Table 80 - Economic Impact on Commercial Navigation under Category 1
(Compared to Basis-of-Comparison)

Plan	Annual Transportation Cost 1985	Annual Transportation Cost 2000	Annual Transportation Cost 2035	Present Worth	Average Annual Amount
	$	$	$	$	$
Basis-of-Comparison:					
United States	794,596,000	1,258,525,000	1,610,034,000	12,568,500,000	1,086,700,000
Canada	553,061,000	794,912,000	954,839,000	8,134,600,000	703,300,000
Total Costs	1,347,657,000	2,053,437,000	2,564,873,000	20,703,100,000	1,790,000,000
6L					
United States	-494,000	-802,000	-1,252,000	-8,172,000	-707,000
Canada	-226,000	-392,000	-536,000	-3,840,000	-332,000
Total Benefits	-720,000	-1,194,000	-1,788,000	-12,012,000	-1,039,000
15S					
United States	-1,468,000	-2,416,000	-3,660,000	-24,403,000	-2,110,000
Canada	-759,000	-1,313,000	-1,780,000	-12,862,000	-1,112,000
Total Benefits	-2,227,000	-3,729,000	-5,440,000	-37,265,000	-3,222,000
25N					
United States	-4,338,000	-7,195,000	-10,949,000	-72,552,000	-6,273,000
Canada	-2,680,000	-4,558,000	-6,056,000	-44,745,000	-3,869,000
Total Benefits	-7,018,000	-11,753,000	-17,005,000	-117,297,000	-10,142,000

Table 81 - Economic Impact on Commercial Navigation Under Category 2
(Compared to the Basis-of-Comparison)

Plan	Annual Transportation Cost			Present Worth	Average Annual Amount
	1985	2000	2035		
	$	$	$	$	$
Basis-of-Comparison:					
United States	794,596,000	1,258,525,000	1,610,034,000	12,568,500,000	1,086,700,000
Canada	553,061,000	794,912,000	954,839,000	8,134,600,000	703,300,000
Total Costs	1,347,657,000	2,053,437,000	2,564,873,000	20,703,100,000	1,790,000,000
6L					
United States	-492,000	-800,000	-1,249,000	-8,146,000	-704,000
Canada	-152,000	-259,000	-329,000	-2,526,000	-218,000
Total Benefits	-644,000	-1,059,000	-1,578,000	-10,672,000	-922,000
15S					
United States	-1,466,000	-2,412,000	-3,656,000	-24,366,000	-2,106,000
Canada	-672,000	-1,152,000	-1,525,000	-11,280,000	-975,000
Total Benefits	-2,138,000	-3,564,000	-5,181,000	-35,646,000	-3,081,000
25N					
United States	-4,333,000	-7,190,000	-10,949,000	-72,498,000	-6,268,000
Canada	-2,522,000	-4,272,000	-5,616,000	-41,930,000	-3,625,000
Total Benefits	-6,854,000	-11,462,000	-16,565,000	-114,428,000	-9,893,000

Table 82 - Economic Impact on Commercial Navigation Under Category 3
(Compared to the Basis-of-Comparison)

Plan	Annual Transportation Cost 1985	2000	2035	Present Worth	Average Annual Amount
	$	$	$	$	$
Basis-of-Comparison:					
United States	794,596,000	1,258,525,000	1,610,034,000	12,568,498,000	1,086,700,000
Canada	553,061,000	794,912,000	954,839,000	8,134,640,000	703,300,000
Total Costs	1,347,657,000	2,053,437,000	2,564,873,000	20,703,138,000	1,790,000,000
6L					
United States	-496,000	-803,000	-1,249,000	-8,184,000	-708,000
Canada	-189,000	-322,000	-416,000	-3,148,000	-272,000
Total Benefits	-685,000	-1,125,000	-1,665,000	-11,332,000	-980,000
15S					
United States	-1,472,000	-2,417,000	-3,657,000	-24,424,000	-2,112,000
Canada	-736,000	-1,266,000	-1,691,000	-12,395,000	-1,072,000
Total Benefits	-2,208,000	-3,683,000	-5,348,000	-36,819,000	-3,184,000
25N					
United States	-4,334,000	-7,189,000	-10,944,000	-72,493,000	-6,268,000
Canada	-2,537,000	-4,291,000	-5,629,000	-42,124,000	-3,642,000
Total Benefits	-6,871,000	-11,480,000	-16,573,000	-114,617,000	-9,910,000

Table 82 (Cont'd) - Economic Impact on Commercial Navigation Under Category 3
(Compared to the Adjusted Basis-of-Comparison)

Plan	Annual Transportation Cost			Present Worth	Average Annual Amount
	1985	2000	2035		
	$	$	$	$	$
Adjusted Basis-of-Comparison:					
United States	794,606,000	1,258,532,000	1,610,032,000	12,568,585,000	1,086,722,000
Canada	553,097,300	794,954,000	954,838,000	8,135,060,000	703,384,000
Total Costs	1,347,703,300	2,053,486,000	2,564,870,000	20,703,645,000	1,790,106,000
6L					
United States	-496,000	-802,960	-1,251,500	-8,178,000	-707,000
Canada	-233,500	-405,600	-553,000	-3,970,700	-343,000
Total Benefits	-729,500	-1,208,560	-1,804,500	-12,148,700	-1,050,000
15S					
United States	-1,470,000	-2,416,000	-3,659,000	-24,412,000	-2,111,000
Canada	-776,100	-1,337,300	-1,802,800	-13,103,000	-1,133,000
Total Benefits	-2,246,100	-3,753,300	-5,461,800	-37,515,000	-3,244,000
25N					
United States	-4,330,000	-7,189,700	-10,951,000	-72,484,000	-6,267,000
Canada	-2,571,000	-4,370,500	-5,795,100	-42,900,000	-3,709,000
Total Benefits	-6,901,000	-11,560,200	-16,746,100	-115,384,000	-9,976,000

losses due to regulation are small compared to the total annual cost of transportation, the economic impact is significant. Most of the losses (60 percent) accrue to the United States fleet since the United States fleet carries more tonnage than the Canadian fleet.

As the lowering effect on Lake Erie increases economic losses increase from $1,039,000 for Plan 6L to $3,222,000 for Plan 15S, and $10,142,000 for Plan 25N per year (Category 1 plans).

Category 2 plans would result in a small reduction in losses to $922,000 for Plan 6L, $3,081,000 for Plan 15S, and $9,893,000 for Plan 25N per year. This reduction in losses occurs because Category 2 plans have higher mean and minimum levels on Lake Ontario while reducing the maximum level compared to Category 1 plans (Tables 40 and 45).

Compared to the basis-of-comparison, Plans 6L, 15S, and 25N under Category 3 would result in average annual losses of $980,000, $3,184,000, and $9,910,000, respectively. Compared to the adjusted basis-of-comparison, Plans 6L, 15S, and 25N under Category 3 would result in average annual losses of $1,050,000, $3,244,000, and $9,976,000, respectively.

The sensitivity of transportation cost analysis to varying levels of traffic growth, length of season, and other factors was examined. For example, a no traffic growth situation for bulk commodities and a high rate representing an unconstrained system and growth of about 2-1/2 percent annually were analyzed to develop a range of possible losses. The no growth situation would result in a decrease of about 15 percent, while unconstrained growth would result in an increase of about 25 percent in the impact of regulation on navigation.

Dredging: The navigation losses described in the previous paragraphs could be eliminated if harbors and connecting channels were dredged deeper to offset the decrease in mean lake level due to limited regulation of Lake Erie (Table 83). That is, if mean lake level were decreased by 0.3 foot and the harbors and channels were dredged 0.3 foot deeper, then there would be no loss in vessel loading. The quantities of material and cost involved in dredging Federal harbors and channels to depths of 1/4, 1/2, and 1 foot, have been determined and curves of depth versus cost plotted for each lake and connecting channel.

It is recognized that it is not possible to dredge to tolerances of 1/4 or 1/2 foot. However, it is considered likely that such dredging would be accomplished during normal maintenance dredging by modifying the contract to pay for the additional depth desired, say 0.3 foot.

It should be noted that Canadian dredging costs are not included. In addition, while the dredging is being accomplished, navigation losses would occur. The navigation losses occurring until dredging is completed must be added to the cost of dredging to determine the full cost to navigation as shown in Table 84.

Table 83 - United States Dredging Costs- An Alternative for Offsetting Commercial Navigation Losses due to Limited Regulation of Lake Erie

Plan	Time Required Accomplish Dredging	Cost of Dredging $ Millions	Present Worth of Future Dredging $ Millions	Equivalent Annual Value $ Millions
6L	10 years	16	11	1.0
	5 years	16	14	1.2
15S	10 years	32	23	2.0
	5 years	32	27	2.4
25N	10 years	74	53	4.6
	5 years	74	63	5.5

Table 84 - United States Dredging Cost Plus Navigation Loss until Dredging is Complete (Millions of Dollars)

Plan	Present Worth Cost of Dredging		Navigation Loss		Total
	10 Years				
6L	11	+	3	=	14
15S	23	+	9	=	32
25N	53	+	29	=	82
	5 Years				
6L	14	+	2	=	16
15S	27	+	6	=	33
25N	63	+	19	=	82

The cost of any dredging required to offset navigation losses resulting from limited regulation of Lake Erie would be an added cost chargeable to the cost of implementing the regulation plan. The cost of commercial navigation and the cost to dredge the connecting channels and United States harbors to offset the lowered mean level are shown in Table 85.

Table 85 - Summary of Navigation Impacts

Plan	U.S. and Canadian Navigation Loss* in Millions $ (Category 3)	U.S. Dredging Cost (In Millions $) Including Navigation Loss until Dredging is Complete	
		10 Years	5 Years
6L	11.4	14	16
15S	36.8	32	33
25N	114.6	82	82

*Source: Table 82

6.3.5 Beach Recreation

The evaluation of the affect of limited regulation of Lake Erie was based on the premise that the altered lake levels due to regulation generate change in beach area. This change in beach area was described in terms of its ability to provide recreational opportunities. By determinig a dollar value for the opportunities realized by recreationists, benefits or losses resulting from regulation could be expressed in monetary terms.

The following assumptions were used:

1. Only beaches accessible to the general public are included;

2. The total number of beaches will remain constant throughout the study period;

3. Expansion of public beach area through acquisition and development will not occur;

4. Swimming is the indicator activity for beach use.

The amount of swimming was deemed to be calculable based on dry beach area which was then converted to recreational beach opportunities. Beach area, then, was considered the measure affected by fluctuating water levels. Changes in lake level due to a regulation plan would result in changes in beach area. The beach area changes then were converted to changes in opportunities available.

Determination of Impact:

Determination of impacts was based on two fundamental steps.

1. Calculation of increased or decreased swimming opportunities due to regulation, which is based on the present and future use of swimming opportunities; and

2. Calculation of the monetary value of an opportunity.

Central to this determination of benefits was establishing when additional opportunities would actually be utilized. Benefits occur when beach use exceeds the number of opportunities available under basis-of-comparison conditions, e.g., if a beach area is larger due to regulation but it is not expected that these additional opportunities will be used, there is no benefit.

Determination of Impact - Calculation of Increased or Decreased Swimming Opportunities:

a. Calculation of Present Beach Use: Canada uses an origin-destination matrix based on Ontario Recreation Survey data (collected in 1974-78) for natural environment swimming in each Ministry of Natural Resources administration district. The United States lacks data at this level of detail and uses an allocation model; a consumptive-type model which indicates level of resource use on an areal basis. The following assumptions were used:

1. Beach use decreases as distance from beach to population centers increases;

2. Competitive attractions affect each use;

3. The work week affects weekly beach use patterns;

These assumptions are implicit in the Canadian origin-destination data.

b. Calculation of Future Beach Use: Future use is a straight line function of population growth in the origin zones over the 50-year evaluation period. The following assumptions were used:

1. Population growth is the primary determinant of growth in beach use;

2. Participation rate will remain constant over the evaluation period;

3. The proportion of beach swimming versus total swimming (including pools, etc.) will remain the same over the evaluation period;

4. The proportion of use from each origin zone will remain the same over the evaluation period.

Determination of Impact - Value of an Opportunity:

The value of an opportunity is determined based on the following:

1. Value of an additional opportunity realized by recreationists is a function of distance traveled and weighted entrance fee for each destination zone;

2. The dollar value for the average distance travelled is based on the cost of driving a private automobile per mile;

3. Entrance fees.

Actual field data and the calculations concerning the beach assessment are presented in Appendix G, Recreational Beaches and Boating.

Evaluation of Regulation Plans: For the study area, each of the regulation plans result in net benefits for beach recreation for each of the categories evaluated. The results are shown in Tables 86, 87, and 88. For each of the plans in each category, the greatest benefits occur on Lake Erie and losses occur on Lake Ontario and the St. Lawrence River. The largest net benefits and losses occur as a result of Plan 25N with Plan 6L having the least impact.

6.3.6 Recreational Boating - U.S. Data Only

Changes in water levels affect recreational boating activity. The impacts measured in this study were effects on recreational boating resulting from owners being prevented safe ingress/egress from the boat slips or moorings due to insufficient depths. Though it was recognized that "damages" to boating activities may result from water levels too high for boat owners to safely use their crafts (e.g., inundated docks), this analysis only considered the effects of low water level "damages." Furthermore, this analysis considered only the effects of water level fluctuations on recreational boating for activities originating at commercial facilities (e.g., marinas). Boats berthed at private residences, summer cottages, etc. were not considered.

Determination of Impacts: Impacts to recreational boating which would result from lake regulation were calculated as the difference in "damages" resulting from any particular lake regulation plan and those "damages" which would occur with the basis-of-comparison conditions. Impacts were measured as benefits or losses.

The method employed in the boating analysis to calculate benefits and losses on recreation boating is explained in detail in three separate sections of Appendix G: Stage-Damage Relationship (3.1), Stage-Duration Relationship (3.2), and Average Annual Damage Computations (3.3). The first of these, stage-damage relationship, is the measurement of the effects of various water levels on boating use. If a given water level as measured at a gauge station on a given day provides an average depth of, say 4 feet at each berth at a particular harbor, then it is assumed that any boat which drafts 4 feet or greater would be unable to safely leave or enter its berth. The basis for calculating this impact in monetary terms is obtained from the "small-boat formula" derived by the U. S. Army Corps of Engineers ("Survey Investigations and Reports-Benefit Evaluating and Cost-Sharing for Small-Boat Harbor Projects," EM 1120-2-113, 11 June 1959).

The "small-boat formula" can be summarized as follows: "Boat owners are assumed to receive nonmonetary returns in the form of boating enjoyment that would be equivalent to the rate of return on investments of comparable size

Table 86 - Economic Impacts on Recreational Beaches, Benefits or Losses Under Category 1

Waterway	Country	Impact of Regulation Plan ($000)					
		Plan 6L		Plan 15S		Plan 25N	
		Net Present Value	Average Annual Value	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value
Lake St. Clair (Including St. Clair River)	Canada	112	10	344	30	803	69
	US	41	4	134	12	404	35
Lake Erie (Including Detroit River and Upper Niagara River)	Canada	2,463	213	6,666	576	18,110	1,566
	US	6,975	603	20,875	1,805	51,604	4,462
Lake Ontario (Including Lower Niagara River)	Canada	NE	NE	NE	NE	NE	NE
	US	46	4	528	46	-121	-10
St. Lawrence River	Canada	NE	NE	NE	NE	NE	NE
	US	-14	-1	-25	-2	0	0
Entire Study Area	Canada	2,575	223	7,010	606	18,913	1,635
	US	7,048	610	21,512	1,861	51,887	4,487
	Total	9,623	833	28,522	2,467	70,800	6,122

NE - Not Evaluated

Table 87 - Economic Impacts on Recreational Beaches, Benefits or Losses Under Category 2

Waterway	Country	Impact of Regulation Plan ($000)					
		Plan 6L		Plan 15S		Plan 25N	
		Net Present Value	Average Annual Value	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value
Lake St. Clair (Including St. Clair River)	Canada	112	10	344	30	803	69
	US	41	4	134	12	404	35
Lake Erie (Including Detroit River and Upper Niagara River)	Canada	2,463	213	6,666	576	18,110	1,566
	US	6,975	603	20,875	1,805	51,604	4,462
Lake Ontario (Including Lower Niagara River)	Canada	-283	-24	-790	-68	-3,106	-269
	US	-312	-27	-601	-52	-1,226	-106
St. Lawrence River	Canada	NE	NE	NE	NE	NE	NE
	US	-81	-7	-58	-5	-116	-10
Entire Study Area	Canada	2,292	199	6,220	538	15,807	1,366
	US	6,623	573	20,350	1,760	50,666	4,381
	Total	8,915	772	26,570	2,298	66,473	5,747

NE - Not Evaluated

Table 88 - Economic Impacts on Recreational Beaches, Benefits or Losses Under Category 3

Waterway	Country	Impact of Regulation Plan ($000)					
		Plan 6L		Plan 15S		Plan 25N	
		Net Present Value	Average Annual Value	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value
Lake St. Clair (Including St. Clair River)	Canada	112	10	344	30	803	69
	US	41	4	134	12	404	35
Lake Erie (Including Detroit River and Upper Niagara River)	Canada	2,463	213	6,666	576	18,110	1,566
	US	6,975	603	20,875	1,805	51,604	4,462
Against Basis-of-Comparison							
Lake Ontario (Including Lower Niagara River)	Canada	NE	NE	NE	NE	NE	NE
	US	-506	-44	-163	-14	-1,592	-138
St. Lawrence River	Canada	NE	NE	NE	NE	NE	NE
	US	-34	-3	-46	-4	-75	-6
Entire Study Area	Canada	2,575	223	7,010	606	18,913	1,635
	US	6,476	560	20,800	1,799	50,341	4,353
	Total	9,051	783	27,810	2,405	69,254	5,988
Against Adjusted Basis-of-Comparison							
Lake Ontario (Including Lower Niagara River)	Canada	NE	NE	NE	NE	NE	NE
	US	-1,134	-98	-787	-68	-2,221	-192
St. Lawrence River	Canada	NE	NE	NE	NE	NE	NE
	US	-34	-3	-46	-4	-75	-6
Entire Study Area	Canada	2,575	223	7,010	606	18,913	1,635
	US	5,848	506	20,176	1,745	49,712	4,299
	Total	8,423	729	27,186	2,351	68,625	5,934

NE - Not Evaluated

in the 'for hire' boating sector and the absence of impediments to boating." The investment upon which the calculations were made is based on the depreciated value of the fleet, which is taken to be equal to 50 percent of the purchased price where:

1. Average age of a boat in the fleet is n/2 (n = life of the asset); and

2. Straight line depreciation is used.

These calculations were carried out for all classes of boats based at the marina facilities.

The second component, the stage-duration concept, is a measure that relates the probability of a water level being equaled or exceeded during a certain period of time. A stage-duration curve was developed for each of the regulation plans and for the basis-of-comparison for each waterbody in the study area. Each stage-duration relationship was derived from May through September water level data for the period 1900-1976. It was assumed that the period May through September, inclusive, represent the recreational boating season throughout the study area. Though recreational boating occurs as early as April and as late as October, many studies indicate that boating in these months (April and October) accounts for a negligible portion of total boating activities.

The third component, the average annual damage computation, represents the integration of the stage-damage and stage-duration relationships. This computation measures the damage that would be expected to occur in any one year. Average annual damage was computed using associated stage-duration relationships for each of the proposed regulation plans and for the basis-of-comparison.

Differences between average annual damages under each regulation plan and the basis-of-comparison were considered the benefits or losses associated with each regulation plan.

Details concerning method, data and calculation are provided in Appendix G.

Evaluation of Regulation Plans: Benefits or losses to recreational boating were calculated as the difference between equivalent average annual damages under basis-of-comparison conditions and those under each of the regulation plans. Equivalent average annual benefits and losses by plan and reach for each of the categories evaluated are listed in Tables 89, 90, and 91. All three regulation plans, 6L, 15S, and 25N, result in a net loss for the entire study area in each category. Regulation Plan 25N produces the greatest loss. It was estimated that losses to recreational boating would not change regardless of the base case used.

Table 89 - Economic Impacts on United States Recreational Boating[1/]
Benefits Or Losses Under Category 1

Waterway	Impact of Regulation Plan ($000)					
	Plan 6L		Plan 15S		Plan 25N	
	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value
Lake St. Clair (Including St. Clair River)	-1,203	-104	-3,296	-285	-8,026	-694
Lake Erie (Including Detroit River and Upper Niagara River)	-4,696	-406	-7,922	-685	-27,561	-2,383
Lake Ontario (Including Lower Niagara River)	763	66	-289	-25	-439	-38
St. Lawrence River	-69	-6	-150	-13	4	0
Entire Study Area	-5,205	-450	-11,657	-1,008	-36,022	-3,115

1/ Impacts of Lake Erie regulation on recreational boating are not available for the Canadian portion of the study area.

Table 90 - Economic Impacts on United States Recreational Boating[1/]
Benefits Or Losses Under Category 2

Waterway	Impact of Regulation Plan ($000)					
	Plan 6L		Plan 15S		Plan 25N	
	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value
Lake St. Clair (Including St. Clair River)	-1,203	-104	-3,296	-285	-8,026	-694
Lake Erie (Including Detroit River and Upper Niagara River)	-4,696	-406	-7,922	-685	-27,561	-2,383
Lake Ontario (Including Lower Niagara River)	671	58	601	52	867	75
St. Lawrence River	46	4	185	16	243	21
Entire Study Area	-5,182	-448	-10,432	-902	-34,477	-2,981

1/ Impacts of Lake Erie regulation on recreational boating are not available for the Canadian portion of the study area.

Table 91 - Economic Impacts on United States Recreational Boating[1/] Benefits Or Losses Under Category 3

Waterway	Impact of Regulation Plan ($000)					
	Plan 6L		Plan 15S		Plan 25N	
	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value	Net Present Value	Average Annual Value
Lake St. Clair (Including St. Clair River)	-1,203	-104	-3,296	-285	-8,026	-694
Lake Erie (Including Detroit River and Upper Niagara River)	-4,696	-406	-7,922	-685	-27,561	-2,383
Against the Basis-of-Comparison						
Lake Ontario (Including Lower Niagara River)	1	0	-393	-34	231	20
St. Lawrence River	-35	-3	93	8	243	21
Entire Study Area	-5,933	-513	-11,518	-996	-35,113	-3,036
Against the Adjusted Basis-of-Comparison						
Lake Ontario (Including Lower Niagara River)	1	0	-393	-34	231	20
St. Lawrence River	-35	-3	93	8	243	21
Entire Study Area	-5,933	-513	-11,518	-996	-35,113	-3,036

1/ Impacts of Lake Erie regulation on recreational boating are not available for the Canadian portion of the study area.

6.3.7 Summary of Economic Evaluations

Tables 92 and 93 are summaries of the economic benefits and/or losses to Great Lakes interests as a result of limited regulation of Lake Erie expressed in terms of present worth and average annual value, respectively. They also contain the costs of the regulatory works in the Niagara River and the remedial works in the St. Lawrence River. Figure 34 shows the results of the Category 1 and 2 evaluations while Figure 35 shows the results of the Category 3 evaluations.

In Figure 34, the horizontal axis represents the annual net increase in the capacity of the Niagara River in thousands of cubic feet per second (TCFS). The vertical axis for the upper half of the figure represents the cost of the Niagara regulatory works in millions of dollars (present worth) corresponding to Plans 6L (3,700 cfs), 15S (9,600 cfs), and 25N (25,000 cfs). The figure shows that as the capacity of the works increases, so would the cost. The vertical axis for the lower half of the figure represents the total benefits or losses to all major economic interests under study, namely coastal zone, hydroelectric power, commercial navigation, and recreational beaches and boating.

For Category 1, which compares limited regulation of Lake Erie with the basis-of-comparison, i.e., the outflow of Lake Erie under present day conditions, the overall economic benefits would be negative, and would become more negative as the capacity of the Niagara regulatory works was increased.

For Category 2, Plan 1958-D has been modified in order to accommodate limited regulation of Lake Erie and satisfy the Commission's criteria for the regulation of Lake Ontario to the same degree as that which occurred without limited regulation of Lake Erie. Thus, it is a comparison of a condition having limited regulation of Lake Erie and a modified Plan 1958-D for Lake Ontario, with the basis-of-comparison. The figure shows that modifications to Plan 1958-D would slightly reduce the expected losses to the major economic interests. A slight net benefit would be expected under Plan 6L. Such a benefit would not be sufficient to offset the cost of the Niagara regulatory works. The total expected benefit would be $1.9 million, present worth. However, the cost of the Niagara regulatory works would be $13.8 million. Thus, for every $7.00 invested, the expected return would be only $1.00, making the project economically unjustified.

For Category 3, Plan 1958-D was modified, and channel enlargements in the St. Lawrence River were included so that Lake Ontario levels would satisfy the Commission's criteria and also accommodate the additional water from Lake Erie. In order to produce a set of levels for Lake Ontario which fall within the criteria, the basis-of-comparison had to be adjusted for the following reasons: 1) the St. Lawrence Seaway and Power Project was designed and built based on the historical supplies through 1954; 2) the project could not cope with the record high supplies of the early 1970's, which exceeded the historical supplies, and still meet the Commission's criteria for the regulation of Lake Ontario; and, 3) any channel enlargement required for the combined regulation of Lakes Erie and Ontario should not be attributed entirely to limited regulation of Lake Erie alone.

Table 92 - Summary of Benefits (Losses) and (Costs) as Present Worth (Millions of Dollars)1/

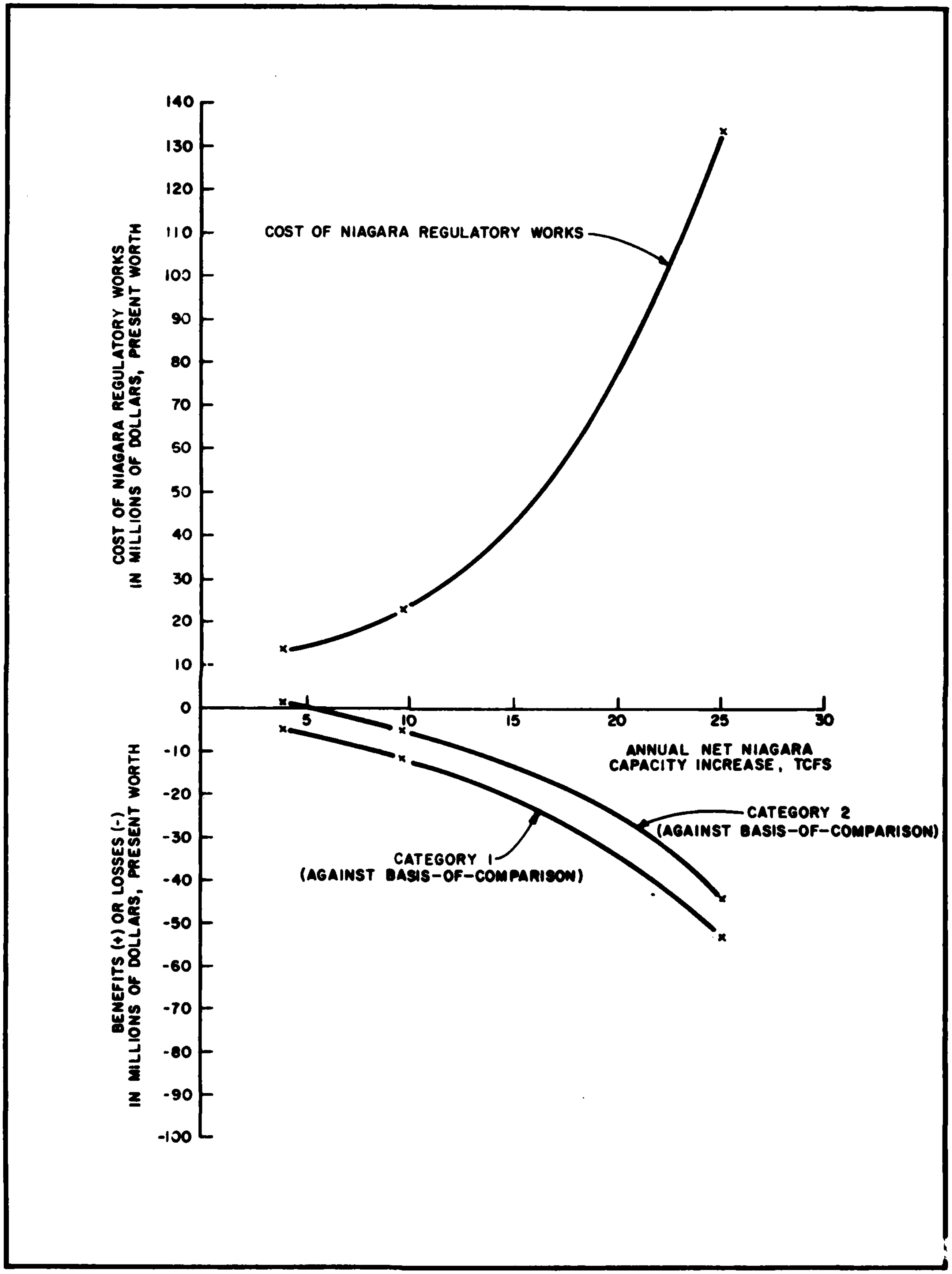
Regulation Plan	6L			15S			25N		
	Against B.O.C.		Against Adj. B.O.C.	Against B.O.C.		Against Adj. B.O.C.	Against B.O.C.		Against Adj. B.O.C.
Category	1	2	3	1	2	3	1	2	3
A. Benefits (Losses)									
Coastal Zone									
U. S.	9.7	9.0	9.8	24.1	23.3	24.7	52.8	51.3	53.2
Canada	2.1	2.1	1.8	3.5	3.3	2.5	7.0	6.3	5.8
Total	11.8	11.1	11.6	27.6	26.6	27.2	59.8	57.6	59.0
Navigation									
U. S.	(8.2)	(8.2)	(8.2)	(24.4)	(24.4)	(24.4)	(72.6)	(72.5)	(72.5)
Canada	(3.8)	(2.5)	(4.0)	(12.9)	(11.3)	(13.1)	(44.7)	(41.9)	(42.9)
Total	(12.0)	(10.7)	(12.2)	(37.3)	(35.7)	(37.5)	(117.3)	(114.4)	(115.4)
Power									
U. S.	(3.0)	3.3	(1.9)	(3.4)	3.3	2.2	(15.7)	(5.0)	(11.2)
Canada	(5.4)	(5.5)	(6.4)	(14.8)	(15.0)	(14.4)	(12.9)	(13.0)	(12.4)
Total	(8.4)	(2.2)	(8.3)	(18.2)	(11.7)	(12.2)	(28.6)	(18.0)	(23.6)
Recreation									
U. S. Beaches	7.0	6.6	5.8	21.5	20.4	20.2	51.9	50.7	49.7
U. S. Boating	(5.2)	(5.2)	(5.9)	(11.7)	(10.4)	(11.5)	(36.0)	(34.5)	(35.1)
Can. Beaches	2.6	2.3	2.6	7.0	6.2	7.0	18.9	15.8	18.9
Total	4.4	3.7	2.5	16.8	16.2	15.7	34.8	32.0	33.5
Total Benefit (Loss)	(4.2)	1.9	(6.4)	(11.1)	(4.6)	(6.8)	(51.3)	(42.8)	(46.5)
B. (Costs)									
Total Regulatory and Remedial Works Cost									
Niagara	(13.8)	(13.8)	(13.8)	(22.5)	(22.5)	(22.5)	(134.2)	(134.2)	(134.2)
St. Lawrence									
1. Required for Lake Ontario Regulation Only			(80.1)			(80.1)			(80.1)
2. Required for Lake Erie Regulation in Addition to 1			0			(16.6)			(5.5)
Total Niagara and St. Lawrence	(13.8)	(13.8)	(93.9)	(22.5)	(22.5)	(119.2)	(134.2)	(134.2)	(219.8)
Total for Limited Regulation of Lake Erie	(13.8)	(13.8)	(13.8)	(22.5)	(22.5)	(39.1)	(134.2)	(134.2)	(139.7)

1/ In July 1979 Price Levels at 8-1/2 Percent Interest

Table 93 - Summary of Benefits (Losses) and (Costs) as Average Annual Values
(Thousands of Dollars)1/

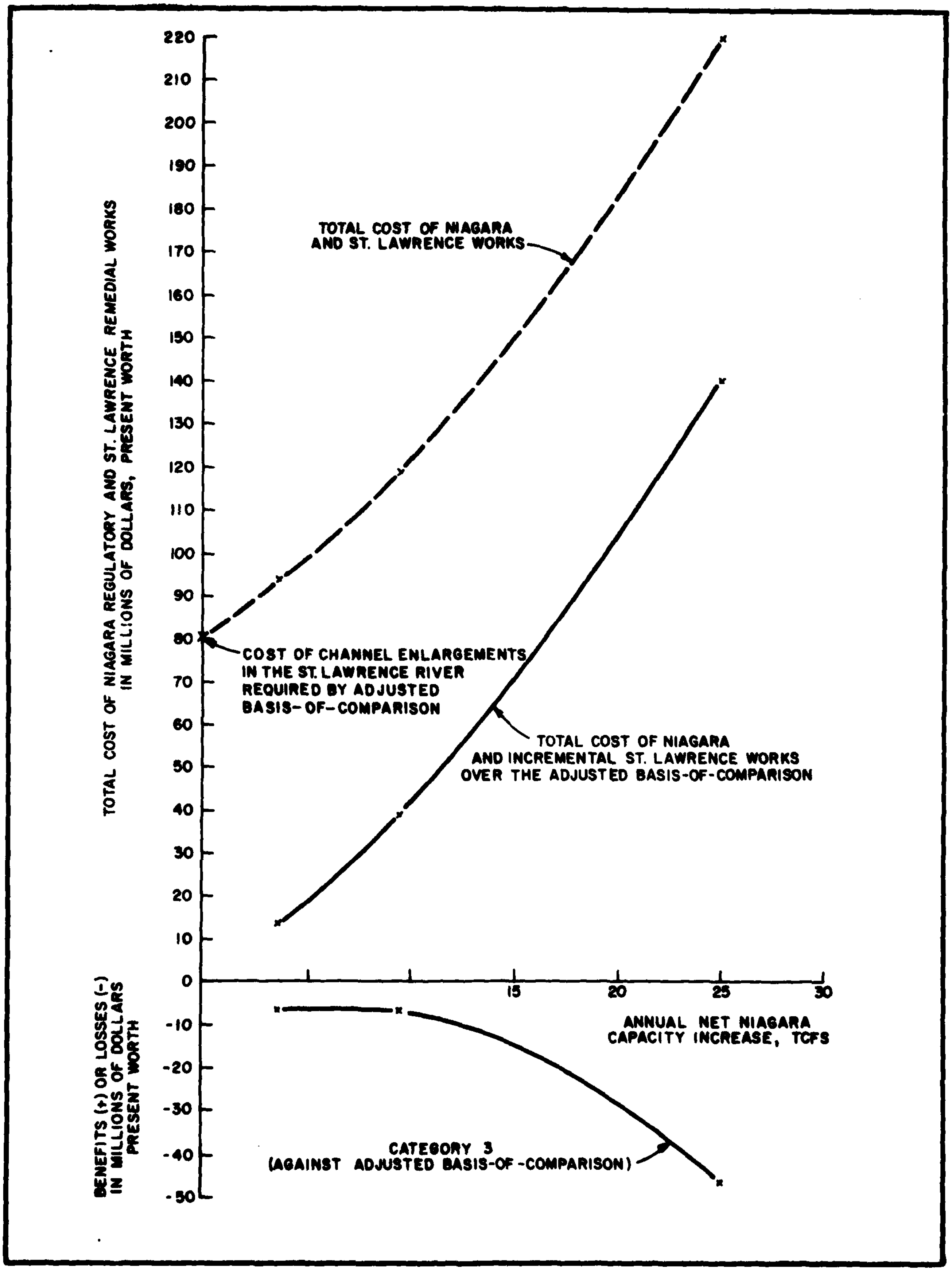
Regulation Plan	6L			15S			25 N		
	Against B.O.C.		Against Adj. B.O.C.	Against B.O.C.		Against Adj. B.O.C.	Against B.O.C.		Against Adj. B.O.C.
Category	1	2	3	1	2	3	1	2	3
A. Benefits (Losses)									
Coastal Zone									
U. S.	838	777	850	2,078	2,012	2,135	4,567	4,436	4,595
Canada	184	180	151	306	286	214	604	547	500
Total	1,022	957	1,001	2,384	2,298	2,349	5,171	4,983	5,095
Navigation									
U. S.	(707)	(704)	(707)	(2,110)	(2,106)	(2,111)	(6,273)	(6,268)	(6,267)
Canada	(332)	(218)	(343)	(1,112)	(975)	(1,133)	(3,869)	(3,625)	(3,709)
Total	(1,039)	(922)	(1,050)	(3,222)	(3,081)	(3,244)	(10,142)	(9,893)	(9,976)
Power									
U. S.	(257)	285	(160)	(291)	288	189	(1,360)	(429)	(967)
Canada	(468)	(476)	(556)	(1,284)	(1,301)	(1,240)	(1,116)	(1,126)	(1,077)
Total	(725)	(191)	(716)	(1,575)	(1,013)	(1,051)	(2,476)	(1,555)	(2,044)
Recreation									
U. S. Beaches	610	573	506	1,861	1,760	1,745	4,487	4,381	4,299
U. S. Boating	(450)	(448)	(513)	(1,008)	(902)	(996)	(3,115)	(2,898)	(3,036)
Can. Beaches	223	199	223	606	538	606	1,635	1,366	(1,635)
Total	383	324	216	1,459	1,396	1,355	3,007	2,766	2,898
Total Benefit (Loss)	(359)	168	(549)	(954)	(400)	(591)	(4,440)	(3,699)	(4,027)
B. (Costs)									
Total Regulatory and Remedial Works Cost									
Niagara	(1,200)	(1,200)	(1,200)	(2,000)	(2,000)	(2,000)	(11,600)	(11,600)	(11,600)
St. Lawrence									
1. Required for Lake Ontario Regulation Only			(6,900)			(6,900)			(6,900)
2. Required for Lake Erie Regulation in Addition to 1			0			(1,400)			(500)
Total Niagara and St. Lawrence	(1,200)	(1,200)	(8,100)	(2.000)	(2,000)	(10,300)	(11,600)	(11,600)	(19,000)
Total for Limited Regulation of Lake Erie	(1,200)	(1,200)	(1,200)	(2,000)	(2,000)	(3,400)	(11,600)	(11,600)	(12,100)

1/ In July 1979 Price Levels at 8-1/2 Percent Interest



SUMMARY OF ECONOMIC EVALUATIONS AND COSTS OF NIAGARA REGULATORY WORKS
CATEGORIES 1 AND 2

FIGURE 34



SUMMARY OF ECONOMIC EVALUATIONS AND COSTS OF NIAGARA REGULATORY AND ST. LAWRENCE REMEDIAL WORKS CATEGORY 3

FIGURE 35

An adjusted basis-of-comparison was therefore developed. The costs of the channel enlargements in the St. Lawrence River, divided to show those required 1) to solve Lake Ontario problems, and 2) for limited regulation of Lake Erie, are shown in Tables 92 and 93.

Coastal Zone (shore property) and beach interests would accrue benefits under limited regulation of Lake Erie for all plans under all three study categories. However, commercial navigation, recreational boating, and hydroelectric power interests would experience losses for all plans for all three categories.

In Figure 35, the data have been plotted on the top curve, showing the total cost to solve both the Lake Ontario and Lake Erie problems, the next curve shows the total cost for Lake Erie regulation alone, and the bottom curve shows the economic assessment of the benefits. The overall economic benefits of all Category 3 plans would be negative, and become more negative as the capacity of the Niagara regulatory works increases.

Lake Ontario regulation problems could be solved by channel enlargements at a cost of $80.1 million, present worth, and by alteration to the plan of regulation, which would increase the frequency of occurrences of high flow in the Montreal area and downstream. Lake Erie regulation problems would require some additional works in the St. Lawrence River for Plans 15S and 25N. The overall losses would be greater than the Category 2 plans, due primarily to higher power and navigation losses.

As mentioned earlier, the total net benefits of all plans for limited regulation of Lake Erie under all study categories would be negative, or (in the case of Plan 6L under Category 2) would have benefits far exceeded by associated costs. In summary, the benefit-to-cost ratio for all plans under all study categories show that limited regulation of Lake Erie would not be economically justified.

6.3.8 Sensitivity Analysis

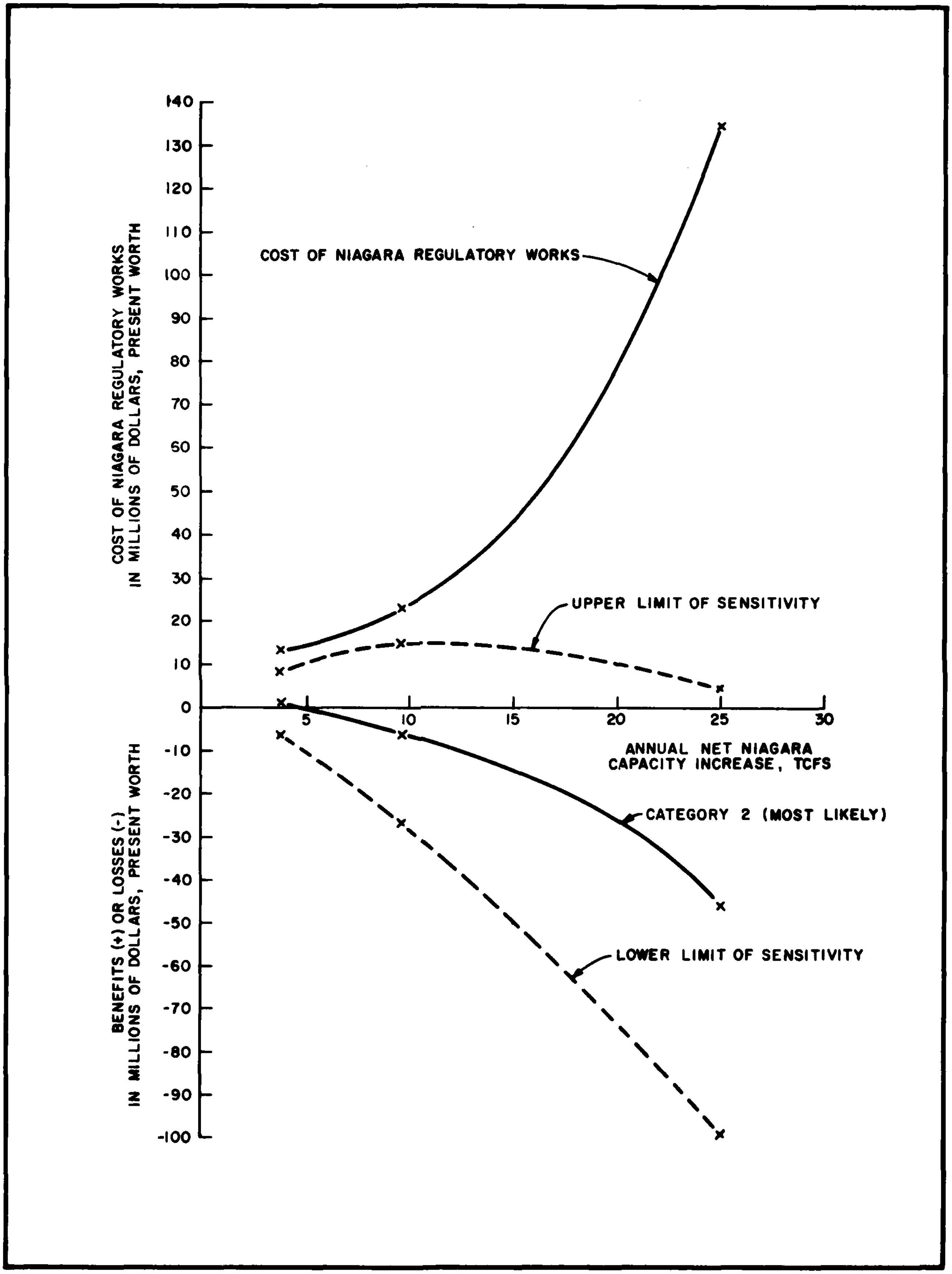
The benefit-to-cost analysis of limited regulation of Lake Erie primarily consisted of a comparison of the probable economic benefits that would be experienced by the major Great Lakes interests, and the costs of the necessary regulatory and/or remedial works. The cost of these works could be computed in precise terms. Similarly, the hydro-electric power interest is an example where well-established methods are available to translate water level and flow changes to precise monetary terms. The probable economic benefits or losses to the other interests studied were based on the best available methodologies and data. As a result, the Board examined how variations in some of the benefits or losses would affect the benefit-to-cost comparison.

Table 94 shows how variations in coastal zone benefits and commercial navigation losses would alter the total economic benefits for Lake Erie Regulation Plans 6L, 15S, and 25N under Category 2. Estimates of coastal zone benefits under an array of assumptions could increase their value to

$17.0 million (present worth) or reduce their value to $6.6 million for Plan 6L. For commercial navigation, estimates of losses could range from $9.1 million to $13.4 million. The ranges of coastal zone benefits and commercial navigation losses for plans 15S and 25N are also shown in Table 94. Figure 36 is a graphical illustration of the results of the table.

Table 94 - Effects of Variations in the Coastal Zone and Commercial Navigation Assumptions *on the Benefit-to-Cost Analysis*

Interest	Benefits (or Losses) under Category 2, in Millions of Dollars, Present Worth		
	Plan 6L	Plan 15S	Plan 25N
Coastal Zone	11.1	26.6	57.6
Upper Limit	17.0	41.9	90.1
Lower Limit	6.6	15.1	32.9
Navigation	(10.7)	(35.7)	(114.4)
Upper Limit	(9.1)	(30.4)	(97.2)
Lower Limit	(13.4)	(44.6)	(143.0)
Power	(2.2)	(11.7)	(18.0)
Recreational (Beaches and U.S. Boating)	3.7	16.2	32.0
<u>Total</u>			
Without Sensitivity Analysis	1.9	(5.7)	(45.1)
Upper Limit	9.4	14.9	4.6
Lower Limit	(5.3)	(26.1)	(98.4)
Niagara R.W. Cost	13.8	22.5	134.2



EFFECTS OF VARIATIONS IN THE COASTAL ZONE AND COMMERCIAL NAVIGATION ASSUMPTIONS ON THE BENEFIT-TO-COST ANALYSIS - CATEGORY 2

FIGURE 36

Section 7

PUBLIC INFORMATION PROGRAM

7.1 Introduction

Particular interest was given to public information concerns during the conduct of this study. In May 1979, the Working Committee established an Ad Hoc Public Information Group, which included two public information professionals, one from Canada and one from the U.S. As alternative solutions were developed and appraised, this Group provided the Working Committee with advice and recommendations concerning the possible public impacts. In addition, this group carried out a public information program that disseminated all the pertinent facts and concepts of concern to the various interests in this study.

7.2 Program Activities

The basic tools used in the program were newsletters and public meetings. Four newsletters were published during the course of the study. The first, published in the Fall 1979, contained general background on the study and attempted to open communication channels between the Study Board and the various interests. By the time of the second newsletter in the Spring of 1980, the work of the subcommittees had progressed to the point that it was possible to explain the different methodologies that were being used to measure the impacts of limited regulation of Lake Erie. The third newsletter revealed the preliminary finding of infeasiblity and announced the location and times for the public meetings that were held in the Fall of 1980. The fourth newsletter, published in the Summer of 1981, announced the submittal of this entire report to the Commission. Each newsletter was sent to at least 6,000 addresses, including shore property owners, environmental organizations, universities, Government agencies and the news media.

The public meetings were held at seven locations around the lower Great Lakes and the St. Lawrence River. The locations were chosen through analysis of the results of a survey that was taken of the readers of the first newsletter. A tear-out card, included in the newsletter, contained questions about preferred meeting locations and could be easily returned to the Working Committee Chairmen's offices.

The purpose of the meeting was to explain the preliminary findings and the study methodologies and to receive comments on the findings. Attendance at the public meetings varied from less than 10 to as many as 50. In most cases, the majority of attendees were shore property owners who expressed skepticism and cynicism regarding the Board's explanation of the factors affecting lake level fluctuations and the study methodology. A popular misconception is that artificial means currently exist which affect the level of Lake Erie and that this "manipulation" of the lake levels is being done for the benefit of power and navigation interests. However, comments were received from some agencies and environmental groups who were in general agreement with the Board.

News media coverage was adequate throughout the study and helped the Board reach a much greater number of persons. The study received the most coverage when the preliminary findings were announced and the public meetings held. Study representatives from the Working Committee Chairmen's offices handled numerous calls from newspapers and broadcast media in the study area.

7.3 Summary

It is the opinion of the Board that the public information program was sufficient to allow all interested citizens to express their concerns. The techniques used were appropriate and effective for a study of this type.

Additional information regarding the Public Information Program is contained in Appendix H.

Section 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

1. LIMITED REGULATION OF LAKE ERIE COULD BE ACHIEVED BY CONSTRUCTING REGULATORY WORKS NEAR THE HEAD OF THE NIAGARA RIVER. HOWEVER, THE COSTS OF SUCH WORKS ARE NOT ECONOMICALLY JUSTIFIED.

By means of regulatory works in the Buffalo, New York - Fort Erie, Ontario area, it would be possible to increase Lake Erie's outflow in order to lower its high water levels. Such regulatory works fall into three types: the modification of the existing Black Rock Navigation Lock; the construction of a Squaw Island diversion channel; and excavation near the head of the Niagara River, along with construction of a compensatory structure. The costs of these works, in terms of present worth at a July 1979 price level, range from about $14 million for the lock scheme to about $134 million for the Niagara River compensatory structure scheme.

2. LIMITED REGULATION OF LAKE ERIE WOULD RESULT IN THAT LAKE'S MAXIMUM, MEAN, AND MINIMUM WATER LEVEL BEING LOWERED. SOME OF THIS LOWERING EFFECT WOULD ALSO BE TRANSMITTED TO THE UPPER GREAT LAKES. THIS LOWERING WOULD BE DUE TO INCREASED LAKE ERIE OUTFLOW DURING PERIODS OF ABOVE AVERAGE WATER SUPPLIES TO THE UPPER GREAT LAKES.

The maximum lowering effect on Lake Erie could be achieved by Lake Erie Regulation Plan 25N, which would require channel excavation with a compensatory structure at the head of the Niagara River. Such regulatory works would provide an increase in capacity of 25,000 cubic feet per second (cfs) and would lower the maximum level of Lake Erie by 1.1 feet. The mean and minimum levels of Lake Erie would also be lowered by 0.6 foot and 0.3 foot, respectively. Since the water level of Lake Erie has a backwater effect on Lakes Michigan - Huron, some of the lowering effect would be transmitted upstream. A small lowering effect could also be transmitted to Lake Superior due to the operation of Lake Superior Regulation Plan 1977. Overall, there would be an increase in the frequency of occurrences of low water levels on Lake Erie and the upper Great Lakes.

3. LIMITED REGULATION OF LAKE ERIE WOULD BRING ABOUT ECONOMIC BENEFITS TO COASTAL ZONE AND RECREATIONAL BEACH INTERESTS. HOWEVER, THESE BENEFITS WOULD BE MORE THAN OFFSET BY LOSSES TO COMMERCIAL NAVIGATION, RECREATIONAL BOATING AND HYDROELECTRIC POWER INTERESTS.

By lowering the water levels of Lake Erie and those of the upper Great Lakes, it would be possible to cause some reduction in the flood and erosion damages to coastal zone properties. Recreational beach opportunities would also be enhanced from increased beach area. At the same time, there would be significant losses to commercial navigation and recreational boating due to reduced navigation depth. Hydroelectric power generation would also experience losses since limited Lake Erie regulation would make more water available at a time when it could not be fully diverted for power generation.

4. THE OVERALL ECONOMIC IMPACT EXPECTED FROM LIMITED REGULATION OF LAKE ERIE IS NEGATIVE. THERE ARE INSUFFICIENT BENEFITS TO OFFSET THE COSTS OF THE REGULATORY AND REMEDIAL WORKS.

Variations in assumptions and evaluative techniques were employed to determine the sensitivity of the study results to such changes as, consideration of uncontrolled development in the coastal zone, and the elimination of capital investments with respect to navigation. Such analyses provide a band of expected economic benefits and losses. There is no reasonable scenario that would result in economic benefits approaching the costs of the regulatory and remedial works.

5. LIMITED REGULATION OF LAKE ERIE WOULD RESULT IN AN INCREASE IN THE FREQUENCY OF OCCURRENCES OF HIGH OUTFLOWS FROM LAKE ONTARIO, INDICATING A REQUIREMENT TO ENLARGE ITS OUTLET IN ORDER TO MEET THE NEEDS STATED IN CATEGORY 3 STUDIES. IN ADDITION, THE EXISTING PHYSICAL DIMENSIONS OF THE ST. LAWRENCE RIVER WERE NOT ADEQUATE TO ACCOMMODATE THE HIGH SUPPLIES OF WATER TO LAKE ONTARIO IN THE EARLY 1970'S AND AT THE SAME TIME SATISFY ALL THE COMMISSION'S CRITERIA AND OTHER REQUIREMENTS FOR THE REGULATION OF THAT LAKE. TO ACCOMMODATE THE LAKE ERIE OUTFLOWS UNDER LIMITED REGULATION OF LAKE ERIE, AND THESE HIGH SUPPLIES, REMEDIAL CHANNEL ENLARGEMENTS WOULD BE NECESSARY IN CERTAIN REACHES OF THE ST. LAWRENCE RIVER.

The channel modifications in the St. Lawrence River completed in 1959 were designed to satisfy the IJC's Order of Approval based on the Lake Ontario historical supply period of 1860-1954. However, even with extraordinary discretionary deviations from Lake Ontario Regulation Plan 1958-D, it was not possible to accommodate the extreme high supplies of the early 1970's and meet all the IJC criteria and other requirements for the regulation of Lake Ontario. Channel enlargements in the International Reach and the Canadian Reach (Lachine Rapids area) of the St. Lawrence River could provide adequate capacities to accommodate the record supplies to Lake Ontario through 1976. For small increases in Lake Erie outflow (Plan 6L), the enlargements to handle the Lake Ontario supplies would also accommodate the Lake Erie water. For higher Lake Erie regulated outflows (Plans 15S and 25N), further enlargements would be needed in addition to those required for

Lake Ontario supplies. An alternative to channel enlargements could be modification of the Commission's present Orders of Approval.

6. CHANNEL ENLARGEMENTS IN THE ST. LAWRENCE RIVER COULD PROVIDE BENEFITS TO LAKE ONTARIO COASTAL ZONE INTERESTS, BUT THE COSTS WOULD NOT BE ECONOMICALLY JUSTIFIED.

Lake Ontario coastal zone interests would benefit by a reduction in high water levels. Lake Ontario levels could be kept within the range prescribed by the Commission's Orders for the supply sequence tested, hence there would be benefits to Lake Ontario coastal zone interests. However, flood and erosion conditions downstream of Montreal would be adversely affected, reducing any benefits expected upstream of Montreal. Furthermore, the costs of such remedial works are not justified by the benefits that could be derived.

7. LIMITED REGULATION OF LAKE ERIE WOULD GENERALLY HAVE A NET ADVERSE IMPACT ON THE ENVIRONMENT EXCEPT FOR CERTAIN WATER QUALITY ASPECTS, SUCH AS TURBIDITY AND PHOSPHORUS, WHERE A SMALL POSITIVE BENEFIT WOULD ACCRUE.

There would be little impact on the general water quality of the lower Great Lakes and the St. Lawrence River. There would, however, be localized adverse effects associated with the construction and operation of any one of the Niagara River regulatory alternatives.

Lowering of average water levels and decreasing the range due to limited regulation would bring about adverse impacts on the wetland-dependent wildlife due to changes and losses in wetland vegetation. Also, fish would experience a decrease in habitat and wetland-produced food.

If channel enlargements were made in the St. Lawrence River, there would be a significant temporary construction-related degradation of water quality, and a permanent loss of desirable marine habitat.

Environmental impact assessments, based on limited available data, were conducted during this investigation. More definitive and costly studies, covering the entire Great Lakes - St. Lawrence River System would have been necessary had any plan for limited regulation of Lake Erie proven to be feasible. Such costs were not included in the Board's estimate of feasibility. Virtually any excavation in the St. Lawrence River will be opposed by both Canadian and the United States interests residing along the river because of probable adverse effects on the local environment.

8. THERE IS A LACK OF CLEAR UNDERSTANDING BY SOME OF THE PUBLIC OF THE VARIOUS NATURAL AND MAN-MADE FACTORS AFFECTING THE GREAT LAKES WATER LEVELS AND THE REASONS FOR THE EXTREME HIGH AND LOW WATER LEVELS.

Many shore property owners do not understand that natural factors are the main cause of lake level fluctuations and that man's ability to control these fluctuations is very limited. Still others erroneously believe that the outflows of Lake Erie are presently being regulated for the benefit of hydroelectric power and navigation interests.

8.2 Recommendations

1. THIS STUDY OF LIMITED REGULATION OF LAKE ERIE SHOULD BE TERMINATED.

Based on the foregoing conclusions, limited regulation of Lake Erie would not be economically justified as a means of reducing flood and erosion damages along the Great Lakes shoreline.

2. A PUBLIC INFORMATION PROGRAM SHOULD BE ENCOURAGED BY THE COMMISSION.

The Commission should encourage an extensive public information program to eliminate the confusion and misconceptions that currently exist.

3. COASTAL ZONE MANAGEMENT PRACTICES SHOULD BE ENCOURAGED BY THE COMMISSION AS A MEANS OF REDUCING FLOOD AND EROSION DAMAGES ALONG THE GREAT LAKES SHORELINE.

In this regard, the Board supports earlier findings which state that "the most promising measures for minimizing future damages to shore property interests are strict land use zoning and structural setback requirements." In Canada, maps showing flood and erosion hazard areas along the Great Lakes shoreline are presently available. Similar information is available in the United States. Appropriate authorities should be encouraged to act to initiate effective coastal zone management practices and structural setback requirements to reduce future damages in the flood and erosion hazard areas on the Great Lakes.

ANNEX A

CONVERSION FACTORS

(BRITISH TO METRIC UNITS)

1 cubic foot per second (cfs) = 0.028317 cubic metres per second (cms)

1 cfs-month = 0.028317 cms-month

1 foot = 0.30480 metres

1 inch = 2.54 centimetres

1 mile (statute) = 1.6093 kilometres

1 ton (short) = 907.18 kilograms

1 square mile = 2.5900 square kilometres

1 cubic mile = 4.1682 cubic kilometres

Temperature in Celsius: $°C = (°F - 32)/1.8$

1 acre-feet = 1,233.5 cubic metres

1 gallon (U.S.) = 3.7853 litres

1 gallon (British) = 4.5459 litres

ANNEX B - LIST OF PARTICIPANTS IN THE STUDY

INTERNATIONAL LAKE ERIE REGULATION STUDY BOARD

U.S. SECTION

Brigadier General Scott B. Smith
U.S. Army Corps of Engineers
Chairman, December 1, 1980 to completion

Major General Richard L. Harris
U.S. Army Corps of Engineers
Chairman, July 3, 1978 to Dec. 1, 1980

Colonel Andrew C. Remson Jr.
U.S. Army Corps of Engineers
Acting Chairman
Feb. 9, 1978 to July 2, 1978

Major General Robert L. Moore
U.S. Army Corps of Engineers
Chairman, June 7, 1977 to Feb. 8, 1978

Wayne S. Nichols
Ohio Department of Energy
Member, June 7, 1977 to completion

David F. Riley
U.S. Fish & Wildlife Service
Member, February 1980 to completion

W.T. Olds, Jr.
U.S. Fish & Wildlife Service
Member, June 7, 1977 to February 1980

Robert A. Cook
New York Dept. of Environmental Conservation
Member, October 1980 to completion

Terence P. Curran
New York Dept. of Environmental Conservation
Member, June 7, 1977 to October 1980

Donald J. Leonard
U.S. Army Corps of Engineers
Secretary, August 11, 1977 to completion

Chris P. Potos
U.S. Environmental Protection Agency
Technical Advisor, June 7, 1977 to completion

CANADIAN SECTION

Derek M. Foulds
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Roy A. Walker
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Fernand Santerre
Hydro Quebec
Member, June 7, 1977 to completion

J.E. Bryant
Department of the Environment
Member, June 7, 1977 to completion

V.J.M. Johns
Department of the Environment
Secretary, August 19, 1978 to completion

R. Beauchemin
Department of the Environment
Secretary, August 11, 1977 to August 18, 1978

ANNEX B - LIST OF PARTICIPANTS IN THE STUDY (Cont'd)

INTERNATIONAL LAKE ERIE REGULATION STUDY WORKING COMMITTEE

U.S. SECTION

Colonel George P. Johnson
U.S. Army Corps of Engineers
Chairman, June 18, 1979 to completion

Colonel Daniel D. Ludwig
U.S. Army Corps of Engineers
Chairman, July 13, 1977 to June 18, 1979

Charles H. Carter
Ohio Department of Natural Resources
Member, July 13, 1977 to completion

Allan C. Tedrow
New York Department of Environmental Conservation
Member, July 13, 1977 to completion

Alvin Hollmer
Power Authority of the State of New York
Member, July 13, 1977 to completion

Dieter N. Busch
U.S. Fish and Wildlife Service
Member, April 1979 to completion

Charles Kulp
U.S. Fish and Wildlife Service
Member, July 13, 1977 to April 1979

Anthony J. Eberhardt
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Secretary, February 6, 1978 to completion

Charles L. Baldi
U.S. Army Corps of Engineers
Secretary, July 13, 1977 to February 5, 1978

CANADIAN SECTION

Albert R. LeFeuvre
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Ray Beauchemin
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Chairman, August 19, 1978 to June 26, 1979

Nicholas Persoage
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John M. Spratt
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Jean-Claude Rassam
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Member, November 25, 1980 to completion

Robert Brisebois
Quebec Hydro Electric Commission
Member, July 13, 1977 to November 24, 1980

Gary B. McCullough
Canadian Wildlife Service
Member, July 13, 1977 to completion

Dave L. Strelchuk
Ministry of Natural Resources
Member, July 13, 1977 to completion

Peter P. Yee
Department of the Environment
Secretary, July 13, 1977 to completion

ANNEX B - LIST OF PARTICIPANTS IN THE STUDY (Cont'd)

INTERNATIONAL LAKE ERIE REGULATION STUDY SUBCOMMITTEES

REGULATION

B.G. DeCooke 1/	U.S. Army Corps of Engineers
D.F. Witherspoon 2/	Canadian Department of Environment
W.P. Erdle	U.S. Army Corps of Engineers
P.P. Yee	Canadian Department of Environment

REGULATORY WORKS

J.A. Foley 1/	U.S. Army Corps of Engineers
D.R. Cuthbert 2/	Canadian Department of Environment
S. Daly	U.S. Army Corps of Engineers
A. Ellis	Canadian Department of Environment
J.N. Erhart	U.S. Army Corps of Engineers
A. Hollmer	Power Authority of State of New York
S. Hung	St. Lawrence Seaway Development Corp.
J.A. McGregor	Ontario Hydro
A.C. Tedrow	NYS Department of Environmental Conservation
P.P. Yee	Canadian Department of Environment

COASTAL ZONE

M.J. Todd 1/	U.S. Army Corps of Engineers
R.J. Moulton 2/	Canadian Department of Environment
D. Brown	Canadian Department of Environment
C. Baghelai	U.S. Army Corps of Engineers
P. Borek	Great Lakes Basin Commission
A. Carpentier	Environment Quebec
R. Clemens	Great Lakes Basin Commission
W. Haras	Canadian Department of Fisheries and Oceans
R. Irvin	NYS - Coastal Management Citizen's Advisory Committee
M. Isoe	U.S. Army Corps of Engineers
J. Kangas	U.S. Army Corps of Engineers
T. Kolberg	Canadian Department of Public Works
J. Kotas	Great Lakes Basin Commission
J.Y. Pelletier	Canadian Department of Environment
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D. Strelchuk	Ontario Ministry of Natural Resources
C. Worte	Canadian Department of Environment

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C. Larsen 1/	U.S. Army Corps of Engineers
C. Lawrie 2/	Canadian Ministry of Transport
R. Lewis	St. Lawrence Seaway Development Corp.
S.R. Heckman	U.S. Army Corps of Engineers

ANNEX B - LIST OF PARTICIPANTS IN THE STUDY (Cont'd)

INTERNATIONAL LAKE ERIE REGULATION STUDY SUBCOMMITTEES

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N. Mangione	Canadian Department of Public Works
R. McIntyre	U.S. Army Corps of Engineers

POWER

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J.M. Spratt 2/	Ontario Hydro
J.C. Rassam	Hydro Quebec Electric Commission
R. Brisebois	Hydro Quebec Electric Commission

ENVIRONMENTAL EFFECTS (Water Quality, Fish, Wildlife, and Recreational Beaches and Boating)

D.N. Busch 1/	U.S. Fish and Wildlife Service
J.T. Urisk 2/	Canadian Department of Environment
C. Cheng	Canadian Department of Environment
E. Angle	Ohio Department of Natural Resources
T. Beaulieu	Canadian Department of Fisheries and Oceans
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D. Gillespie	Canadian Department of Environment
R.J. Guido	U.S. Army Corps of Engineers
R. Haas	Michigan Department of Natural Resources
A. Holder	Ontario Ministry of Natural Resoruces
R. Hore	Ontario Ministry of Environment
H. Johnson	Canadian Sea Lamprey Control Centre
R. Kenyon	Pennsylvania Fish Commission
E. Krakowski	Canadian Department of Environment
C. Kulp	U.S. Fish and Wildlife Service
M. Marshall	Ontario Ministry of Natural Resources
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E, Megerian	U.S. Army Corps of Engineers
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W. Pearce	NYS Department of Environmental Conservation
C.P. Potos	U.S. Environmental Protection Agency
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W. Shepherd	NYS Department of Environmental Conservation
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T. Vogel	Ohio Department of Natural Resources
B. Williamson	U.S. Army Corps of Engineers

ANNEX B - LIST OF PARTICIPANTS IN THE STUDY (Cont'd)

INTERNATIONAL LAKE ERIE REGULATION STUDY SUBCOMMITTEES

AD HOC ECONOMICS

R. Guido	U.S. Army Corps of Engineers
T. Muir	Canadian Department of Environment

AD HOC PUBLIC INFORMATION

A.J. Eberhardt	U.S. Army Corps of Engineers
P.P. Yee	Canadian Department of Environment
H.R. Fredenburg	U.S. Army Corps of Engineers
J. Lloyd	Canadian Department of Environment
J. Hall	Consultant
E. McGuinness	Consultant

1/ U.S. Section Chairperson

2/ Canadian Section Chairperson

COVER PHOTO

Niagara River at Buffalo, N.Y. and Fort Erie, Ontario, with Lake Erie in background. April 18, 1979.

Taken by POWER AUTHORITY OF THE STATE OF NEW YORK.

COVER DESIGN: James Lloyd

DATE

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